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BROOKLYN BOTANIC GARDEN

CONTRIBUTIONS
No. 26

PLANT COMPOSITION AND SOIL ACIDITY OF A MAINE BOG

BY

BARRINGTON MOORE AND NORMAN TAYLOR

BROOKLYN, N. Y.
1922

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PLANT COMPOSITION AND SOIL ACIDITY OF A MAINE BOG*

BARRINGTON MOORE AND NORMAN TAYLOR[1]

Mt. Desert Island lies off the eastern coast of the state of Maine in latitude 44° north and longitude 68° west. The island is of peculiar interest on account of its unusual assemblage of plants and animals, and its remarkable influence on man.[2]

The predominant vegetation is northern, with a number of arctic alpine plants, a few of which elsewhere in this latitude occur only above timber line; and yet there is a mixture of southern forms. The same mixture of northern and southern forms is found in the insect fauna of the island. There are here presented brief observations on the plants of a small bog on the south side of the island near the village of Bass Harbor.

The bog in question is about fifty yards long by twenty-five wide and appears to be due to an undrained depression in a wide granite ledge. The granite, which comprises the hills of the island (extending over 1,500 feet elevation) and much of the more level parts, is pink in some places and gray in others, and rather coarsely crystalline. It cooled at a considerable distance below the surface and was later exposed by erosion.[3] The granite in this case was pink, made up of quartz, potassium feldspar, a little mica, and hornblende.

The bog proper contains no open water and is covered chiefly with sedges. Around the margin of the bog is a stunted rather open growth of black spruce with a mixture of larch, *Larix laricina,* and a little Arborvitae, *Thuja occidentalis,* none of the trees exceeding ten feet in height. A few feet beyond this margin there are in places outcrops of the granite ledge on which grow plants of peculiar interest. Three sites, quite different edaphically, are represented in an area not exceeding an acre in size. Two of these sites, the bog proper and the rock ledge, are xerophytic, the former from lack of moisture, the latter from the character of its water. The marginal site, or forest, which merges with the surrounding forest, is mesophytic.

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* Contributions from the Brooklyn Botanic Garden 26.

[1] Presented before the Ecological Society at its meeting in Chicago, December, 1920.

[2] The plants have been partially listed by Rand and Redfield in their "Flora of Mt. Desert Island, Maine," John Wilson and Son, Cambridge, Mass., 1894. The forest types have been briefly described by Moore in "Some Factors Influencing the Reproduction of Red Spruce, Balsam Fir and White Pine" Jour. For. Vol. 15, No. 7, pp. 827–853, 1917.

[3] Shaler, N. S. "Geology of Mt. Desert Island" U. S. Geol. Survey, 8th Ann. Rept. of the Director, 1889.

The acidity of the soil in each of the three sites was tested by Dr. Wherry's field method.[4] In the bog proper the water under a growth of sedges which probably represents the earlier stages of succession, and also the water from under a tussock of sphagnum amongst roots of *Chamaedaphne* and cranberry, which appears to be a later stage than the sedge, had a specific acidity of 300+, or P_H 4.5. The water squeezed by hand from the peat under the sedge had a specific acidity of 300; that squeezed from the sphagnum under the *Chamaedaphne* was 1,000, or P_H 4.0. The latter value is the highest acidity found on Mt. Desert Island out of a considerable number of tests made up to this time (July, 1920).

On the rock ledge there was no soil except the humus from the plants themselves, mixed with a small amount of mineral particles. The humus in which were growing the roots of the crowberry, *Empetrum nigrum,* had a specific acidity of 100, P_H 5.0. It will be noticed that this acidity is much lower than that in the bog proper.

Tests in the forest at the margin of the bog revealed a surprisingly low degree of acidity in both the humus and underlying mineral soil. The humus, mostly dark decomposed sphagnum, under a black spruce tree, was 5 inches deep and had a specific acidity of only 10, P_H 6.0. Beneath this humus the mineral soil, apparently decomposed granite, is of an ashy gray color so characteristic of the soil just beneath the humus in the coniferous forests of the northeast. This mineral soil, without admixture of humus, showed a specific acidity of 10. In amongst the roots of a small Arborvitae, *Thuja occidentalis,* at the edge of the bog, the humus had a specific acidity of 300, P_H 4.5, which is the highest on which this tree has been found growing by the writers.

The three sites, it will be seen, ranged from comparatively low to high acidity, and the stage of vegetative succession corresponded with the degree of acidity, the earlier stage showing the strongest reaction. But this should not be taken as indicating a general principle, because the red spruce forest, which is later than any of the stages on the area in question, shows an acidity in the surface humus of 300+.

Almost two months later, at the end of August, the bog had, owing to an unusually dry season, lost a large proportion of its water, and tests showed that there had been a considerable decrease in acidity. The water squeezed from brown sphagnum had an acidity of 500, P_H 4.0 to 4.5. The underlying black muck, representing a more complete stage of decomposition, had a specific acidity of 100. Beneath this was a mucky grayish clay, which seems to correspond with the gray soil in the marginal forest, but appears to be considerably finer and to have more colloidal material. It appears that the drying up in the summer, instead of making the acids stronger through higher concentration, has somewhat diminished their intensity, probably through oxidation.

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[4] Wherry, E. T. "Soil Acidity and a Field Method for its Measurement." Ecology, Vol. 1, No. 3, pp. 160–173, 1920.

Some plants are confined to one site, while a few grow on all three. One striking effect of the diverse habitats will be obvious after consideration of the plants growing on the bog proper, on its predominately woody fringe, and on the rocky ledge at its north end.

The open bog is dominated by *Carex atlantica, Carex oligosperma, Rynchospora fusca,* and *Eriophorum angustifolium.* The first three make up a dense mat in all the lower parts of the bog, while the *Eriophorum* is scattered freely through the other sedges. On mounds of Sphagnum and often over nearly exclusive tussocks of *Polytrichum strictum* there is a group of secondary species, which, arranged in the order of frequency, is as follows:

Chamaedaphne calyculata
Rhododendron canadense
Kalmia angustifolia
Vaccinium Oxycoccus
Ledum groenlandicum
Sporobulus uniflorus
Carex canescens
Carex cephalantha
Calopogon pulchellus
Solidago uniligulata
Eriophorum virginicum
Carex paupercula
Carex oligosperma
Drosera intermedia
Larix laricina (seedlings only)

The general distribution of these plants shows that in the bog proper 25 percent are Arctic-Alpine, 25 percent Hudsonian, 18.7 percent Canadian, while 31.3 percent are plants of such general distribution as to be of little significance.

The forest at the edge of the bog proper is slightly higher than the open sedge vegetation of the middle of the bog. This fringe, with here and there obvious intruders from the open bog, is made up of the following species, also arranged in order of frequency:

Chamaedaphne calyculata
Larix laricina (small trees)
Ledum groenlandicum
Rhododendron canadense
Picea mariana (about 10 feet tall)
Spiraea latifolia
Thuja occidentalis
Gaylussacia baccata (in the water!)
Viburnum cassinoides
Betula populifolia
Nemopanthus mucronata

Unlike the bog proper, this assemblage of plants shows no Arctic-Alpine affinities, 36.4 percent being of Hudsonian, 36.4 percent Canadian, and 27.2 percent of widely distributed species.

Upon the rocky ledge there are certain species not found in either of the other localities. Those found on the actually dry rocky ledge are floristically related to those of the physiologically dry bog. Larch, however, which is a tree of moist situations, is more abundant on the rocky ledge than on the bog proper. The plants of the flat rock ledge are as follows, again arranged in order of frequency:

Empetrum nigrum (covering much of the ledge)
Larix laricina
Chamaedaphne calyculata
Kalmia angustifolia
Myrica carolinensis
Picea mariana
Pyrus melanocarpa
Gaylussacia baccata
Myrica asplenifolia
Thuja occidentalis
Cornus canadensis
Pinus resinosa
Betula populifolia
Vaccinium pennsylvanicum
Vaccinium pennsylvanicum angustifolium
Amelanchier oblongifolia
Alnus crispa mollis

As to their geographical affinities, these species may be assigned to Arctic-Alpine 6.3 percent, Hudsonian 31.2 percent, Canadian 37.5 percent, and the remaining widely distributed species 25 percent.

The affinities of the three sites are summarized in the following table:

	Arctic Alpine	Hudsonian	Canadian	Widely distributed
Bog proper	25%	25%	18.7%	31.3%
Woody fringe of the bog		36.4%	36.4%	27.2%
Rocky ledge	6.3%	31.2%	37.5%	25%

It is interesting that the arctic alpine plants are here found only on the two sites representing the earlier stages of succession, and that as the succession advances there is a diminution in the alpine plants.

Summary

Brief observation of a small bog near Bass Harbor on Mount Desert Island, Maine, showed the specific acidity in the bog proper to run from 300— to 1,000, P_H 4.5 to 4.0, the acidity of the humus under roots of crowberry, *Empetrum nigrum*, on a granite ledge within a few feet of the bog to be 100, and that of the black spruce forest around the bog to be 10, P_H 6.0. The floristic composition of these three sites is quite different. The bog proper contains 25 percent of arctic alpine species, the rock ledge 6.3 percent, and the marginal forest none. Thus the arctic alpine plants are here found only on the earlier stages of succession.

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BROOKLYN BOTANIC GARDEN

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No. 27

THE ORIGIN OF NEW VARIETIES OF NEPHROLEPIS BY ORTHOGENETIC SALTATION

II. REGRESSIVE VARIATION OR REVERSION FROM THE PRIMARY AND SECONDARY SPORTS OF BOSTONIENSIS

BY

R. C. BENEDICT

BROOKLYN, N. Y.
1922

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THE ORIGIN OF NEW VARIETIES OF NEPHROLEPIS BY ORTHOGENETIC SALTATION

II. REGRESSIVE VARIATION OR REVERSION FROM THE PRIMARY AND SECONDARY SPORTS OF *BOSTONIENSIS*[1]

R. C. BENEDICT

(Received for publication June 30, 1921)

INTRODUCTION: A REVIEW OF THE CHARACTERS OF THE PROGRESSIVE SPORTS

A description of the regressive variations of *Nephrolepis exaltata* var. *bostoniensis* requires some review of the characters of the progressive sports of this form.[2] The nature of these may most simply be indicated by tabulating the outstanding facts relating to them.

1. The progressive varieties so far described all have had their origin by *vegetative* sporting from *N. exaltata* var. *bostoniensis*, or its derivatives. Reproduction is by bud plants on slender stolons.
2. Over *one hundred* new varieties have appeared spontaneously at various florists' establishments in the last twenty years.
3. All these varieties have been *discontinuous*, *i.e.*, separated from the parent form by a definite break in characters—in other words, saltations or mutations. These new varieties have not intergraded by slight differences into their parent forms.
4. The evolution of these forms has been *orthogenetic*, that is, they have developed in series in which each character is successively intensified in succeeding forms. There are three such orthogenetic series:

> (*a*) Division series: *bostoniensis*, once pinnate—*Piersoni*, twice pinnate—*Barrowsi*, more completely twice pinnate—*Whitmani*, three times pinnate—*Smithi*, four times pinnate—*Craigi*, five times pinnate.
>
> (*b*) Ruffling series: *bostoniensis*, with nearly plane pinnae—*Roosevelti*, pinnae ruffled—sport of *Roosevelti*, pinnae more ruffled and lobed.
>
> (*c*) Dwarfing series: *bostoniensis*—*Scotti*—*Wagneri*, and *bostoniensis*—*Giatrasi*—sport of *Giatrasi*; the second and third forms in each case are successively smaller than *bostoniensis*.

As further evidence of orthogenesis may be cited the fact that combinations of these three types of variations may occur. Thus, dwarfing may appear in the division series and in the ruffling series, and division may appear in the dwarfing series (*cf.* chart, page 144).

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[1] Brooklyn Botanic Garden Contributions, No. 27.

[2] For a full account, see Bull. Torrey Bot. Club 43: 207–234. Pl. 10–15. 1916.

5. The varieties, even in a single series, are almost invariably characterized by several *associated differences.* Thus *Giatrasi,* which is half the size of *bostoniensis,* differs also in the possession of red, wiry, somewhat sinuous petioles and rachides, and by differently shaped pinnae. In only a few cases is there but one distinguishing character obvious.

6. The new varieties are *stable, i.e.,* they reproduce themselves true to type in a high percentage of cases. Occasionally in the division-series forms, reverting leaves may appear; that is, leaves with less division than is typical; and furthermore, new runner plants may develop which show a return in characters toward the parent form. The latter are uncommon, however, and, as will be indicated later, are actually new saltations or mutations. Some varieties have not as yet been known to show any variations from type.

7. The progressive varieties have been *infrequent.* If reversions are uncommon, as noted in the preceding paragraph, new progressive forms have been much more so. Of the millions of plants of the original *bostoniensis* variety grown for sale, only six or eight sports have been reported. The large number of one hundred progressive sports in twenty years has been due to two factors: to the fact that millions of these plants are grown each year and that florists are on the watch for new forms, and to the fact, also, that the coefficient of mutation has been higher in some of the derived varieties than in *bostoniensis* itself.

As a basis for the description and comparison of the reversionary forms, reference is here made to the revised chart of the relationships of the progressive varieties considered in the earlier paper. The revision consists mainly in the omission of a few forms of some uncertainty of origin and of no particular interest in connection with the present paper. *Schilleri* and *Schultheisi,* before attributed to *bostoniensis* as primary sports, are not in circulation in the trade or likely to be. *Wittboldi,* included doubtfully in the *bostoniensis* chart of the earlier paper, may almost certainly be eliminated from any such relationship. Although no plants have been obtainable from the original producer, specimens have been received from a number of sources, French, English, and American, which by reason of their exact agreement in characteristics may be considered authentic. Judged from this material, *Wittboldi* is a variety of some species other than *exaltata,* to which it was originally attributed. It probably belongs with *biserrata.* At any rate, it is of no interest in the present paper.

The position of the three- to four-pinnate *Amerpohli,* originally placed as a primary sport of *bostoniensis,* has been changed to bring it opposite varieties of a similar amount of division. No more evidence of its exact origin is available, but since this is in doubt in any event, it seems best to place it with similar forms. *Smithi* and *Craigi,* originally attributed in doubt to *Amerpohli*, have also had their position changed, and on the basis of close resemblance have been placed with the sports of *Whitmani* to which they are probably related.[3]

THE NATURE OF REGRESSIVE VARIATION

It is common knowledge that some of the Boston-fern varieties as they are obtained from the florist fail to remain entirely true to type. The most familiar manifestation of this aberration occurs in some of the division forms: thus, in a plant of some twice or thrice pinnate variety there may appear one or more once pinnate leaves, and similar leaves may continue to be developed together with the typical leaves of the given variety. The resultant plant often shows a distressingly mixed or mongrel appearance. This sort of reversion is, however, only one of several types, the others being relatively frequent in florists' establishments. The purpose of the present paper is to describe these various types of reversion, both the products and, as far as possible, the processes. The term "reversion," which will be used interchangeably with "regressive variation," is here applied to any modified form which shows a change from some progressive variety back toward *bostoniensis*. Thus, the production by a variety with leaves twice or more pinnate of leaves less divided than the typical form is called a reversion. The production by a dwarf form of a plant with larger leaves is also considered as reversion, and likewise the reduction of ruffling. Broadly, we may recognize three manifestations of such reversion.

1. The simplest possible type is seen in the appearance of single aberrant, *i.e.*, reverting leaves among others which are typical. This is a common occurrence in varieties in the division series.

2. Again, we may find all the new leaves of a single crown or stem axis appearing reverted in form; *e.g.*, in a plant of a thrice-divided variety the typical leaves may be succeeded by once pinnate leaves developed one at a time until the former appearance of the crown is entirely altered.

3. The third type of reversion occurs when the change in character takes place in one of the branch reproductive shoots or stolons, and appears only when from this stolon new bud plants develop which manifest the new character (Pl. IX, fig. 1).

The first two types may be designated as "crown" reversion, partial and complete, and the second may be called "runner" reversion. Only the crown type may be actually watched in the external manifestations of the process. Runner reversion is known only in its products, *i.e.*, the new forms developed as bud plants on lateral stolons. The cytological changes are scarcely even a matter for conjecture, the evidence dealt with here being entirely macroscopic.

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[3] It may be of interest to some to know that a considerable set of varieties of these Nephrolepis sports may be obtained from John Lewis Childs, Floral Park, New York. At present the Childs catalogue lists 30 different forms representing all types of variation listed in the chart, both progressive and regressive. The stock plants are grown separately, and the identification of the varieties offered may be generally relied upon.

The study of regressive variation offers one distinct advantage over that of progressive variation in the fact that the former is sufficiently common to be frequently observed, and may thus be studied experimentally. This suggests the possibility of determining an external cause for reversion. So far no definite experiments have been carried on, but there are some suggestive facts connected with the possible relations between cultural conditions and the occurrence of some of the reversions.

As with the first paper, the data for the present article have been obtained in two ways: first, by the further extension and study of the collection of Nephrolepis at the Brooklyn Botanic Garden. Some of the reversions here described have been developed at the Garden under observation. Second, visits to florists have been continued for the opportunity of seeing hundreds of thousands of plants. During 1916 these visits were made with the aid of a grant from the American Association for the Advancement of Science. A second similar grant was made in 1917 and has served in the preparation of this paper. Acknowledgment is also made to the Bureau of Plant Industry, specifically to Messrs. Peter Bisset, Wilson Popenoe, and David Fairchild, for assistance in the collection of wild forms of Nephrolepis from various parts of the tropics.

Special acknowledgment is again tendered the Brooklyn Botanic Garden for the very satisfactory facilities for this study which have been enjoyed.

Description of the Regressive Varieties

It will forward the description of the regressive variations to state here one of the conclusions based on the detailed observation of all the forms: namely, regressive variations may be expected to occur in any of the progressively developed varieties. This statement has not been checked for all the one hundred varieties known to exist, nor even for the forty listed in the genealogical chart attached herewith, but it has been found true for so many of them that it is a reasonable assumption that it may be characteristic of all.

This multiple origin of reversionary forms makes it impossible to arrange their descriptions in as simple a system as was used for the progressive varieties. With the latter it was merely a case of arranging them in a genealogical table, and describing for each the changes or advances in form it manifested. Each new kind in a series was produced by the intensification of some character of the parent type, or by the appearance of some other of a few well marked characters. Each reversion represents similarly some definite divergence from its parent form, but instead of one common ancestral type there are forty to one hundred possible ancestors. The reversion of any given variety is thus a distinct problem for study and description, and is related to other reversions only as it may produce analogous or comparable forms. Because of this extremely complex material, the present paper will deal mainly with what are believed to be representative types of regressive reversions.

GENEALOGICAL CHART OF PROGRESSIVE SPORTS OF BOSTONIENSIS

Black face type indicates division sports. Italics indicate sports showing ruffling. Plain Roman type indicates dwarfing. Small capitals indicate other types of variation.

EXALTATA. *bostoniensis*
- **Piersoni**. . . .
  - **Barrowsi**. . . . . **Whitmani**. . . . .
    - WHITMANI "IMPROVED"
    - **Whitmani compacta**
    - Elmsfordi
    - **magnifica**
    - **gracillima**
    - **Goodi**
    - **? Smithi**. . . . . **Craigi**
    - SUPERIOR
  - SPLENDIDA
  - superbissima. . muscosa
  - **elegantissima**. ELEGANTISSIMA "IMPROVED"
  - **elegantissima compacta**. . . . **sport like Whitmani compacta**
  - PIERSONI "IMPROVED"
- **Anna Foster** **?? Amerpohli**
- *Harrisi*. . . . . . *Wm. K. Harris*
- *Roosevelti* . .
  - *Sport like Wm. K. Harris*
  - Teddy Jr. . .
    - Dwarf sport . . . . FISH-TAIL SPORT
    - Randolphi
    - Smallest dwarf
- Scotti. . . . .
  - FALCATA
  - Wagneri
  - **Scholzeli**. . . . . **Three-pinnate sport**
- Giatrasi. . . .
  - New Jersey
  - **Queen Sophie**
- GRETNAI

Since the progressive varieties all originated from one form, *bostoniensis*, it will be interesting to consider first the primary sports of that fern. To what extent has the original process been reversed? After that, the reversion of the different grades of the division series will be considered. What are the products of the reversion of twice pinnate forms, of thrice pinnate forms, etc., etc.? Are the progressive steps each retraced in reversion? Can a four-times-pinnate variety produce thrice, twice, and once pinnate reversions, or only one of these? Similar questions suggest themselves in connection with the dwarfing and ruffling series, and will be considered in order.

Reversions of the Primary Sports of Bostoniensis

Before the reversions of the primary sports of *bostoniensis* are dealt with, it will be worth while to consider the possible reversion of *bostoniensis* itself. *Bostoniensis* differs from the wild species, *exaltata*, from which it must have originated, in certain vegetative characters—it has laxer, broader, more numerous leaves—and also in producing only abortive sporangia. The wild species is abundantly fertile, and the spores germinate readily. In *bostoniensis*, however, the sporangia abort at an early stage, apparently before the tetrad division. The resulting sporangia are small and shriveled, but there are usually enough of them to produce fruit dots of considerable size and the gross appearance of fertility.

Of the actual reversion of *bostoniensis* to a fertile condition there is no authentic record. There have been many attempts on the part of florists to produce plants by planting the soral material and there have been a few reports of success, but the reports have told nothing of the condition of the plants from which the spores (?) were obtained, *i.e.*, whether the original plant had first reverted in reproductive and vegetative characters as well, or whether the fertile spores were a chance production on a plant otherwise like ordinary *bostoniensis*.

There is nothing inherently improbable in either of the above suggested contingencies. An approximation to vegetative reversion may frequently be seen in plants which have been grown in untoward conditions of light, temperature, and food. In these plants the leaves assume a stiffer, more erect habit, decidedly suggestive of the appearance of the wild species but without its condition of spore fertility. Favorable conditions cause a return to the normal *bostoniensis* characters. It may be noted, however, that real reversion might occur frequently in florists' establishments without being observed, because the difference in appearance between the sterile and the fertile sori is not calculated to attract the attention of the average grower, and also because a reverted plant would probably be discarded as undesirable.

The primary progressive sports of *bostoniensis*, as listed in the revised chart, comprise four types: (1) Division sports, *Piersoni* and *Anna Foster;* (2) Dwarf sports, *Scotti* and *Giatrasi;* (3) Ruffled sports, *Harrisi* and *Roosevelti;* and (4) a "fish-tail" or forked-leaf form, *Gretnai*. The possible and actual reversions may be best considered under the same categories.

Piersoni. The history of *Piersoni* is illuminating. I am indebted for the following facts to J. C. Trevillian, who has been in charge of the fern houses at F. R. Pierson's Tarrytown establishment since and before the origin of *Piersoni*, the first of a long line of Pierson varieties.

The first break from the once pinnate form came as a small two-leaved runner in a stock bed of *bostoniensis*. Both the first two leaves were twice pinnate. This small plant was set apart and most carefully cherished. As proved by later developments, it was worth many times its weight in gold. Its third leaf must have been a disappointment, for it represented a return to the once pinnate form and may therefore be considered the original example of reversion. Thenceforward the original *Piersoni* plant and the thousands of progeny of this variety have always shown a mixture of leaf types: *viz.*, typical twice pinnate, once pinnate, and intermediates on which entire, lobed, and divided pinnae may co-exist. Even a single pinna may show all three grades of division (Pl. V, figs. 1–6).

Not only is there variation in leaf division on a single plant at any given time, but there seems also to be seasonal variation or possibly variation according to different cultural conditions. In April, 1916, a group of about fifty stock plants of *Piersoni* was observed in the John Lewis Childs Floral Park greenhouses which were almost completely in a once-pinnate condition. The plants were growing set out in rich soil in a well lighted bench. Most of them possessed only once pinnate leaves, but their identity was not possibly in doubt both because records had been kept of the planting and because of subsequent history. Three of these stock plants possessing only once pinnate leaves were selected for special observation with the thought that they might represent permanent reversion to a once pinnate condition. After being potted up at the Botanic Garden they were given good conditions of lighting, etc. The new leaves which followed were mainly of the twice pinnate type. Since then, all the plants of this origin kept at the Botanic Garden are predominantly twice pinnate, although cultural conditions have not been continuously at the optimum.

The experience with the Childs plants just described bears out a conclusion which Trevillian has reached after twenty years' experience with Nephrolepis varieties: *viz.*, that during the less favorable cultural conditions of winter, all the division varieties tend to produce more reverted leaves than in the more favorable six months from April onward. It is a well established fact that all *bostoniensis* varieties show a recognized slowing up in the number of new leaves produced during winter, and apparently associated with this is a tendency to produce leaves with less division. It may be concluded, then, that the maximum development of the special characteristics of any form depends upon an optimum of cultural conditions, and that it is therefore with Nephrolepis varieties partly a matter of season. The Childs plants above cited presented an extreme case of seasonal fluctuation.

The condition of *Piersoni* with respect to the amount of leaf division may be described as a state of "fixed instability." Taken as a whole, the variety represents a distinct and definite saltation from *bostoniensis*, but the jump or variation was not all the way to a stable twice pinnate type although the predominant leaf form throughout the year and normally at any time of the year is twice pinnate. The amount of reversion noted in the Childs plants referred to above is exceptional. Twice pinnate leaves are usually in the majority at all times of the year. That the divided-leaf condition is fixed is well illustrated by the experience with the Childs plants just related. Although externally those plants had lost all indications of the twice pinnate character, continued cultivation showed that it had been only temporarily obscured. It seems a safe conclusion that the actual basis of the original *Piersoni* variation from *bostoniensis* must have been a protoplasmic change which maintained itself even though temporarily not evident in the gross characters.

The facts detailed thus far—the appearance of once pinnate leaves in *Piersoni* stock—represent no real regressive variation or reversion but rather fluctuation within the limits of the *Piersoni* type. There are, however, three possible types of unmistakable reversion which should be considered.

The occurrence of a complete and discontinuous reversion to a once-pinnate form is highly probable. The fact that there is no record of such a reversion does not alter the probability. The florist would not be likely to detect its occurrence. *Bostoniensis* is almost invariably grown wherever any of its varieties are in cultivation, and the appearance of a once pinnate plant among *Piersoni* stock ordinarily would be passed over as a misplacement of a *bostoniensis* plant. As will be described below, this type of permanent reversion is well known in other varieties.

Partial reversion to a condition of greater instability is postulated on the basis of the behavior of other varieties considered below. This change would result in a strain in which the number of twice pinnate leaves would be fewer than in the best strains.

The most interesting reversion attributable to *Piersoni*, or, indeed, to any other *bostoniensis* variety, is a plant of the *Piersoni* type of division, but one the exact origin of which is unfortunately shrouded in doubt. I obtained it from the New York Botanical Garden where it was being grown under the name of a totally different variety and species, *Nephrolepis hirsutula tripinnatifida*. Its earlier history is unknown, but two explanations of its origin are possible. It may represent a progressive twice pinnate sport from wild fertile *exaltata* of which the New York Garden has plants from several collections in Porto Rico; or it may represent a reversion in fertility from some plant of *Piersoni* which has been grown there for the nineteen or twenty years since its introduction. The latter explanation seems the more probable. In any event, it is unique among *Nephrolepis exaltata* forms in its fertility, and a particular interest attaches to it in the possible type of its spore progeny of which several separate sowings are being grown and will be reported on later.[4]

Anna Foster (Pl. V, figs. 7–12) represents a twice-pinnate form also in a state of unstable division like that of *Piersoni* but even more pronounced. It was the first of all the Boston fern sports to be reported, but seems always to have been so unstable and so much less attractive than *Piersoni* that it never gained much general popularity. In well developed plants about half the leaves show the double pinnation, but this is never so completely developed as in good *Piersoni* leaves. The best leaves are partly once pinnate, and most of the divided pinnae are incompletely divided. At the present day, twenty years after its appearance, there has come down one strain attributable to *Anna Foster* which shows only an occasional twice pinnate leaf. Such a plant presumably represents reversion from the more completely divided original type.

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[4] For purposes of reference and discussion, I have assigned the name "*fertilis*" to this form. Technically its name should read, *Nephrolepis exaltata bostoniensis* var. **fertilis**.

Harrisi and *Roosevelti.* These two varieties, possessing almost identical leaf forms, may be dealt with together as far as possible reversions are concerned. No reversions are known. The conditions in this respect are almost exactly like those discussed in connection with the possible complete reversion of *Piersoni* to a once-pinnate form. Florists who grow the ruffled forms almost always grow *bostoniensis* as well, since the cultural conditions required are the same. If a complete reversion should occur, it would pass unnoticed or be interpreted as a chance *bostoniensis* plant accidentally associated.

Scotti. Exactly the same conditions prevail with *Scotti* as with *Roosevelti* and *Harrisi.* No reversions have been detected, not even occasional fluctuating leaves.

Gretnai. The fish-tail form, *Gretnai,* shows fluctuations in the degree in which its pinnae and leaf tip fork, but the character is always present to some extent. No complete reversion to the normal Boston-fern type has been noted.

Giatrasi. This fern represents one of the most distinct of all mutations from *bostoniensis* shown in the primary sports. *Piersoni,* while differently divided, has the same habit and size, and produces continually some similar leaves. *Giatrasi,* on the contrary, differs so markedly in size, habit of growth, and leaf characters that its separation as a "species" could easily be justified. Its leaves attain a length of no more than one third that of *bostoniensis;* the petioles are darker colored and wiry, those of *bostoniensis* being greenish and herbaceous; the pinnae are shorter in proportion, blunter, and wavier, the midribs are often sinuous, and the plant is notably slower in growth.

Giatrasi (Pl. VIII, fig. 2) does not produce any single fluctuating leaves, but it has produced as a runner sport (at the Giatras establishment) a form which may well be considered a reversion. This new form was introduced to the trade under the name of the "*New York*" fern (Pl. VIII, fig. 1). In characters it is intermediate between the Boston fern and *Giatrasi,* possessing in considerable degree all the characters of the latter fern except that it is considerably larger although never equalling *bostoniensis* (Pl. VIII, fig. 3) in height. There is no indication of "fixed instability" here. Both *Giatrasi* and the "*New York*" fern are discontinuous and stable sports, without fluctuations *inter se*.

The case of the *New York* Nephrolepis emphasizes a fact true in general for reversions: complete return to all the characters of the parent form rarely if ever occurs. The original progressive variations were not mere fluctuating changes about a mean, but decided and permanent changes which must find their explanation in some cytological alteration of definite character.

Summarizing, we may note the following types of reversion among the primary progressive sports of *bostoniensis:*

1. A reduction in the stability of the original progressive change, as shown by a permanent decrease in the proportion of divided leaves in *Anna Foster* and probably also in *Piersoni*. It is possible that this type of reversion should be considered as a fluctuation.
2. A possible reversion (mutation) to a fertile condition, with the *Piersoni*-like form from the New York Botanical Garden as an illustration (Pl. V, figs. 13–17; Pl. VI, fig. 6).
3. A reversion (mutation) from a dwarf form to a size intermediate between the dwarf and *bostoniensis* (Pl. VIII).

N.B. The production of single atypic leaves does not constitute reversion but rather merely part of the normal variability of a given plant (Pl. V, figs. 1–17).

Reversions of the Secondary Sports of Bostoniensis

Reversions of superbissima (Pl. VIII, fig. 6).

The simplest examples of reversion among the secondary sports of *bostoniensis* have occurred in plants of the variety *superbissima*. This is a dwarfed sport from *Piersoni*, and differs from the latter form almost entirely in a foreshortening of the rachis and of the midribs of the pinnae. The actual amount of green tissue does not seem to be proportionately reduced. As a result of this brachytic type of dwarfing, the leaves have a crowded and congested appearance. In type of division and stability of leaf division, *superbissima* seems to be exactly like *Piersoni*. In the course of a year any given plant is sure to produce a good many once-divided leaves. Two distinct reversions have been noted and are represented by forms which have been continuously cultivated.

The first of these was introduced as a new variety by Pierson under the name of *viridissima* (Pl. VIII, fig. 5), given on account of its dark green color, presumably the result of the congestion of leaf tissue. This form is of the same size as *superbissma* and has the same rigid thick rachides, but is entirely once pinnate like *bostoniensis*. In other words, it represents a reversion in one of the two progressive characters of *superbissima*, that of leaf division. The plants of *viridissima*, as grown for some years, have continued constant, and show no indication of fluctuating variations toward a more divided form.[5] A second instance of this reversion has also taken place at the Brooklyn Botanic Garden in material of *superbissima* obtained originally from the city greenhouses of Fairmount Park, Philadelphia. So far it has not been sufficiently grown to allow an opinion as to its identity with Pierson's *viridissima.*

From *viridissima*, although no fluctuating variation has been observed, there has developed in at least two establishments a further reversion of stable character, in this case one of size. This new form (Pl. VIII, fig. 4), which has not received any name, is taller and laxer, thus intermediate in size and habit between *viridissima* and normal *bostoniensis.* It has not, however, made complete return to *bostoniensis* size but is comparable to the "*New York*" fern, described on a preceding page as a reversion from *Giatrasi.* Like that form, it is stable in its characters, and it may here be noted as a general observation that the mutations showing reduced size are invariably more stable than those presenting differences in amount of leaf division. This semi-dwarf mutation from *viridissima* was first noted by Trevillian in the Pierson establishment. Since then I have found it also in the greenhouses of Peter Wagner of Brooklyn.

From *superbissima* there has developed directly another reversion in size (Pl. VIII, fig. 7), but which has retained the double division of both *superbissima* and *Piersoni.* This also was first noted in the Pierson greenhouses where it has developed in *superbissima* stock more than once. It has also occurred in the greenhouses of John Lewis Childs at Floral Park, and likewise at the Brooklyn Botanic Garden. A description of the circumstances of this last occurrence is worth recording.

In a pot of *superbissima* which included three or four crowns, there developed in one crown two leaves considerably taller and looser in division. The crowns were then potted separately for observation. That containing the two taller leaves developed more of the same sort of leaves, becoming eventually intermediate in size between *superbissima* and *Piersoni.* Additional plants were raised from it of the same sort, and the form remained stable in further cultivation.

It should be noted here that the several reversions of this particular type have not resulted in exactly identical forms. The different plants are all intermediate between *superbissima* and *Piersoni* but there are some variations in height and shape of the segments.

Special interest attaches to the three reversionary forms above described because of their very definite character. Each represents a single return toward the original Boston-fern type. In all three cases the new forms were immediately stable in their own type. That is, there was no tendency to fluctuate toward the parent forms. It is also of interest, as has been noted by Babcock and Clausen (*Genetics in Relation to Agriculture*, pp. 315, 316), that these changes in leaf form and size occur independently of each other, indicating that the protoplasmic basis of the changes is also distinct—"to factor mutations in vegetative reproduction."

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[5] Since the above sentence relating to *viridissima* was written, a further variation has taken place in this form, first noted in the summer of 1921. In the only plant of *viridissima* being maintained, what appears to be a definite return to the characteristics of *superbissima* has occurred, so that there is now no authentic plant of the original Pierson *viridissima* sport in the Botanic Garden collection.

Reversions from elegantissima-compacta.

The form *elegantissima-compacta* has given rise to more distinct reversions than any other variety. It may be recalled here that it, like *superbissima*, represents a doubly progressive sport from *Piersoni*, showing both increased leaf division and reduction in size. In its dwarf character it does not have the foreshortened and congested aspect of *superbissima*, and its leaves are somewhat more divided, being twice pinnate-pinnatifid (Pl. IX, fig. 2; Pl. X, figs. 1–3). This division is also considerably more stable than that of *Piersoni* or *superbissima*, although reverting leaves occur not infrequently, and consequently seasonal changes may also occur. These, however, do not affect the type of the plant, which continues year after year to hold the characters of the original variation. By analogy from *superbissima*, we should expect at least the two types of reversion found in that plant, the production of a taller twice-pinnate plant and of a once-pinnate form. As a matter of fact, both these expected forms and one other have developed.

The simplest form is a complete reversion to the once-pinnate condition, first found at the Pierson establishment and sold by them under the name "Dwarf Boston" (Pl. X, fig. 4). This form is of about the same size as the primary progressive sport *Scotti*, and under some conditions rather closely resembles this. It has typically, however, more the appearance of *bostoniensis* in leaf form and habit. It is stable in that no divided leaves are produced from it. As it is somewhat taller than *elegantissima-compacta*, it is to be considered also a reversion in size as well as in division.

Another distinct and definite reversion has been introduced under the name of "*John Wanamaker*" (or *Wanamakeri*) by Robert Craig of Philadelphia (Pl. X, figs. 13–18). This is an incomplete reversion in division in which some of the leaves are entirely once pinnate but considerably ruffled and wavy, while others are more or less lobed or even twice pinnate but also showing the ruffling. The leaves are taller and narrower than those of *elegantissima-compacta*, even when divided. The variety seems to represent reversion toward double division reaching only an intermediate condition. In its ruffled character it might be considered to present a progressive sport in this particular, but it seems more reasonable in this case to interpret this ruffling as a modification of leaf division.

This same form has arisen several different times at the Pierson greenhouses and also at Giatras's place in West Hoboken. These different examples of this mutation vary a little in form and size, but are, in general, very like each other.

A plant of this type obtained originally at Pierson's and set out in an open stock bed at the Brooklyn Botanic Garden underwent an interesting change in that it returned entirely, in crown and runners, to apparently the original type of *elegantissima-compacta*. There might be reason for suggesting that the growth in an open bench had something to do with it except for the fact that in many thousands of plants grown under the same conditions at Craig's I did not see any similar break. The explanation is probably found in the possibility that the particular number which I obtained from Pierson did not really represent a stable sport or mutation but rather a fluctuation of a type which will be described below.

From the *Wanamaker* type there has developed at Pierson's a reversion to a completely once pinnate unruffled form, corresponding to "Dwarf Boston" in general appearance and size (Pl. X, fig. 5), but not sufficiently cultivated to warrant any general opinion as to its characters. It corresponds to the reversion from *viridissima* described above since it represents a second step back toward *bostoniensis*.

In addition to the above mentioned, Trevillian has also detected among the plants in his charge another *elegantissima-compacta* mutation which approaches *Piersoni* in characters, *i.e.*, it is twice pinnate and tall. Two examples from Pierson's have been grown at the Botanic Garden (Pl. VI, figs. 2, 3). By reference to the illustrations it will be seen that there is some little difference in the shape and size of the ultimate segments of these two types. Both, however, are generally like the *Piersoni*-like reversions produced from *superbissima*, and, it may be added, like other similar reversions from progressive sports of a higher order of leaf divisions. A series of leaves of six of these types, produced by mutation from five different progressive sports representing several different grades of leaf division, is illustrated in Plates VI and VII. Thus figure 1, Plate VI, shows a reversion from *Smithi*, a four-pinnate form. Attention is called to the fact that the six types, although alike in division, vary noticeably in outline and carriage of the pinnae, in texture, and in minute characters.

When it is recognized that each of the twenty derivative mutations from *Piersoni* noted on the chart may give rise directly or indirectly to reversions of a *Piersoni* type, the possibilities of a confused tangle of forms, practically impossible to differentiate by description, will be realized. What explanation could the ordinary systematic examination of such a group of forms bring forth? Some systematists would explain the variation as a set of closely related intergrading forms, connecting the extremes as parts of one single "species." With fertile sexually reproducing forms, the suspicion of hybridism would certainly attach. Especially would this apply in such cases in which the reversion was intermediate in form and other characters. Obviously, if we may consider these vegetative mutations as analogous to variations among wild forms which appear similar, we may see adequate reason for caution in making generalizations regarding complexes of wild forms.

The reversions of *elegantissima-compacta* described above all belong to the category of stable forms, presenting distinct and definite changes in leaf form and division. The kind of reversion mentioned earlier in the paper as reduced stability of division ("fixed instability") has also occurred, and one case has been under continuous observation and cultivation for several years.

A plant of typical *elegantissima-compacta*, obtained directly from its place of introduction, the Pierson establishment, was one of the original group of *bostoniensis* varieties to be received in 1915, and in fact was designated "no. 1." in my accession series. With the other forms then at hand, it was planted out in open soil in a bench for reproduction by runners. Among its numerous progeny in that first cultivation was one small plant with leaves almost entirely once pinnate. In the spring of 1916 (March) this was planted in a large square pan for further propagation with the idea that it might prove to be a stable once pinnate reversion. At this time it consisted of six leaves (Pl. IX, fig. 1, shows a similar plant), entirely once pinnate with the exception of one which was shallowly lobed on some pinnae. By August the pan had become full of small plants which were separately potted and grown for eleven months. Although the stock crown had been almost completely once pinnate, these runner plants were in general like typical *elegantissima-compacta* in leaf division, with scattered once pinnate leaves mixed in. In July, 1917, the stock consisted of fourteen plants in four- and six-inch pots, but not in the best condition, owing to crowding. Three sorts of plants could be distinguished among them. One plant with fifteen or more leaves was almost entirely once pinnate, only one or two leaves showing any double division. There is little doubt that this represented the original once pinnate crown first detected, but this cannot be absolutely assured. Nine plants were mainly twice pinnate as in typical *elegantissima-compacta*, but each had one or more once pinnate leaves. Four plants had leaves practically without any reversion.

The cultural conditions had been the same for all, so that the modifications observed must have taken place as a result of internal changes. Examples of the three sorts were kept for further observation, but their subsequent behavior was the same. The plant with mainly once pinnate leaves continued once pinnate in its original crown, but the secondary crowns produced in the same pot by runners to the number of eight had leaves mainly of the twice-divided type of *elegantissima-compacta*. In other words, the original once pinnate crown, produced as a runner variation, retained its leaf characteristics as its own new leaves developed, but gave rise only to new plants with more divided leaves, either like typical *elegantissima-compacta* or, in some cases, with the less stable amount of division, but with no real modification of leaf form (Pl. X, figs. 6–12).

This behavior is worthy of emphasis because it has been found to be of frequent occurrence in the study of reversion among other division forms.

On more than one occasion and with diverse varieties, attempts to reproduce some reverting leaf type by setting out the new form in bench for vegetative reproduction have resulted in the continuance in the new crown of its new characteristics but with the reappearance in the runners derived from it either of the original form of division or of that form with some reduced stability. The larger size of the reverted crown is typical generally of reversions, both temporary and permanent sorts.

With these facts in mind, exception must be taken to the conclusion adopted by Boshnakian (Jour. Hered. 7: 233. 1916) and repeated by Babcock and Clausen (*Genetics in Relation to Agriculture*, fig. 130 and explanatory description), interpreting a series of four connected Nephrolepis runners which show differences in form as four different mutations. The series shows respectively (1) a four-pinnate variety, *magnifica;* (2) a derived once pinnate plant; (3) a third generation (?) plant with unstable division, and (4) another third generation (?) plant like *magnifica.* Similar series of runners have occurred in my cultures (Pl. IX) which on further cultivation have resolved themselves into the three types of plants cited above, *viz.*, (*a*) second generation reverted crowns, usually only one; (*b*) third generation crowns, like the original variety in division and in stability of division; (*c*) other third generation crowns like the original variety but with more reverted leaves per plant. Unless the plants figured by Boshnakian were afterwards planted and found to continue distinct, it is not safe to cite them as so many mutations; rather, they seem to belong in the category of fluctuations. It has been my experience that while a plant of a divided variety may often produce occasional reverted leaves and sometimes a new runner plant with only reverted leaves, the production of a stable self-reproducing reversion, in other words a mutation, is most uncommon.

In general, any given division variety may be expected to produce in cultivation one of three types of plants. The most numerous—an overwhelming majority—will be of the form typical for the parent stock, the only modification being in occasional single reverting leaves such as occur in the stock plants themselves. Second, an occasional plant will be developed which will appear almost entirely reverted but which, on further reproduction, will develop new plants like those of the original form, or at most with some reduction in stability of division. Such plants would be classed as fluctuations. It is obviously important for growers in selecting crowns for propagation to avoid such undesirable stock plants. Very rarely, a third type of plant will appear, distinct not only in its own characteristics but also in its runner progeny, a real mutation. These are somewhat more common in the regressive direction than in the progressive.

There is a very interesting morphological problem involved in this matter of the production of new forms, whether of regressive or of progressive type. The problem can only be indicated here, but the main facts are worthy of note. It is a well known fact that the stolons of Nephrolepis originate in association with the leaves, one stolon being paired with each leaf in branching from the crown-stem axis. It should not be difficult to determine whether there is any association between leaf variations on the original crown and runner variation on the paired stolon. For example, do the stolons paired with reverting leaves tend to produce new plants showing a reduction in stability of leaf division in a manner analogous to the behavior in variegated Pelargonium?

The problem is not as simple as might at first appear from the above statement, because the relation of stolon to old and new plants is not entirely simple. The stolon from an original stock plant may bear along its several feet of length a considerable number of plants arising as lateral buds, generally on short spur branches. When the new bud plants are taken up for potting, each one may retain some portion of the parental stolon capable of continued bud reproduction. The progeny of such a plant would then consist of new plants from the original parental stolon together with others from the new stolons of the bud plant, *i.e.*, "sisters" and "daughters." With the possibility of such complications, the doubts expressed with reference to the relationships of the series of four connected plants figured by Boshnakian will be readily appreciated.

A not infrequent anomaly in the behavior of the stolons is what appears as a dichotomy of a stolon in which one half becomes a leaf without any evident associated stem axis while the other half continues as a normal stolon. I have seen three successive leaves produced in this manner on one stolon. Sometimes the stolon growing point is lost with the formation of a single leaf, and the appearance is given of the transformation of a stolon into a leaf. I have made no determination of the stelar behavior in these cases.

Reversions of other secondary sports.

Only one other secondary sport of *bostoniensis* has been recorded as having given rise to a reversion of the mutation type, another Pierson variety, *elegantissima*. This is a variety much like *elegantissima-compacta* in leaf division, but lacking the dwarf character of that form. Robert Craig of Philadelphia has reported and introduced as a new variety, named *robusta*, a form which has almost complete agreement in characteristics with plain *Piersoni* (Pl. VI, fig. 5). If its origin is correctly given, it is to be grouped with the other *Piersoni*-like reversions which have already been discussed.

Summarizing the facts recorded for the reversions of the secondary sports, we find the reversionary behavior similar to that described for the primary forms.

1. Reduction in the stability of the original progressive change as shown in the degree of division and in the proportion of divided leaves was experimentally demonstrated. Furthermore, this reduction was shown in *elegantissima-compacta* to pass through an almost completely reverted

form, and then to return in the next generation either to the original typical form or to one with reduced stability of division. The point is, there are cases of apparent reversion in which the new (*i.e.*, reverted) form seems incapable of reproducing its new type. Its runner progeny do not "breed true" but return in different degrees to the form from which the reversion originally sprang. The possibility suggests itself that such unstable variations may correspond in kind to the variations noted as probably due to seasonal changes. It may be that as reverted leaves appear to be more frequent during winter, long continued observation might also show that the temporarily reverted runners, the sort incapable of reproducing their kind, may also have a seasonal frequency.

2. Discontinuous variation in a regressive direction affecting the leaf division has been found in a number of forms: in *elegantissima*, to *robusta*, a *Piersoni*-like form; in *elegantissima-compacta*, in two steps through *Wanamaker* and to a once-pinnate form; also in *elegantissima-compacta*, in one step, to "Dwarf Boston," once pinnate; in *superbissima*, to *viridissima*.

3. Discontinuous variation, reversion in size: in *elegantissima-compacta*, to *Wanamaker*, and to a *Piersoni* type; in *viridissima*, to a taller form, intermediate in size between *viridissima* and *bostoniensis*.

4. No evidences of reversion to a fertile condition have been noted.

The characteristics and behavior of reversions from tertiary and higher degree progressive sports of *bostoniensis* will be left to a future paper for description.

Brooklyn Botanic Garden

EXPLANATION OF PLATES

Plate V

Fluctuating reversion: pinnae showing range of fluctuation in three forms.

Figs. 1–5. Pinnae from one leaf of *Piersoni*, ranging from typical twice pinnate division (fig. 1) through intermediate forms (figs. 2–4) to once pinnate type (fig. 5)

Fig. 6. Simple pinna from another leaf of the same plant of *Piersoni* as shown in figures 1–5.

Figs. 7–10. Pinnae from one leaf of "*Anna Foster*."

Figs. 11, 12. Pinnae of *Anna Foster*, taken from another plant.

Figs. 13–17. Pinnae of fertile *Piersoni*-like reversion, var. *fertilis*, showing same sort of fluctuation as in true *Piersoni*.

Plate VI

Regressive mutations: leaves of twice pinnate reversions from different progressive forms.

Fig. 1. From *Smithi*, a four-times-pinnate form.

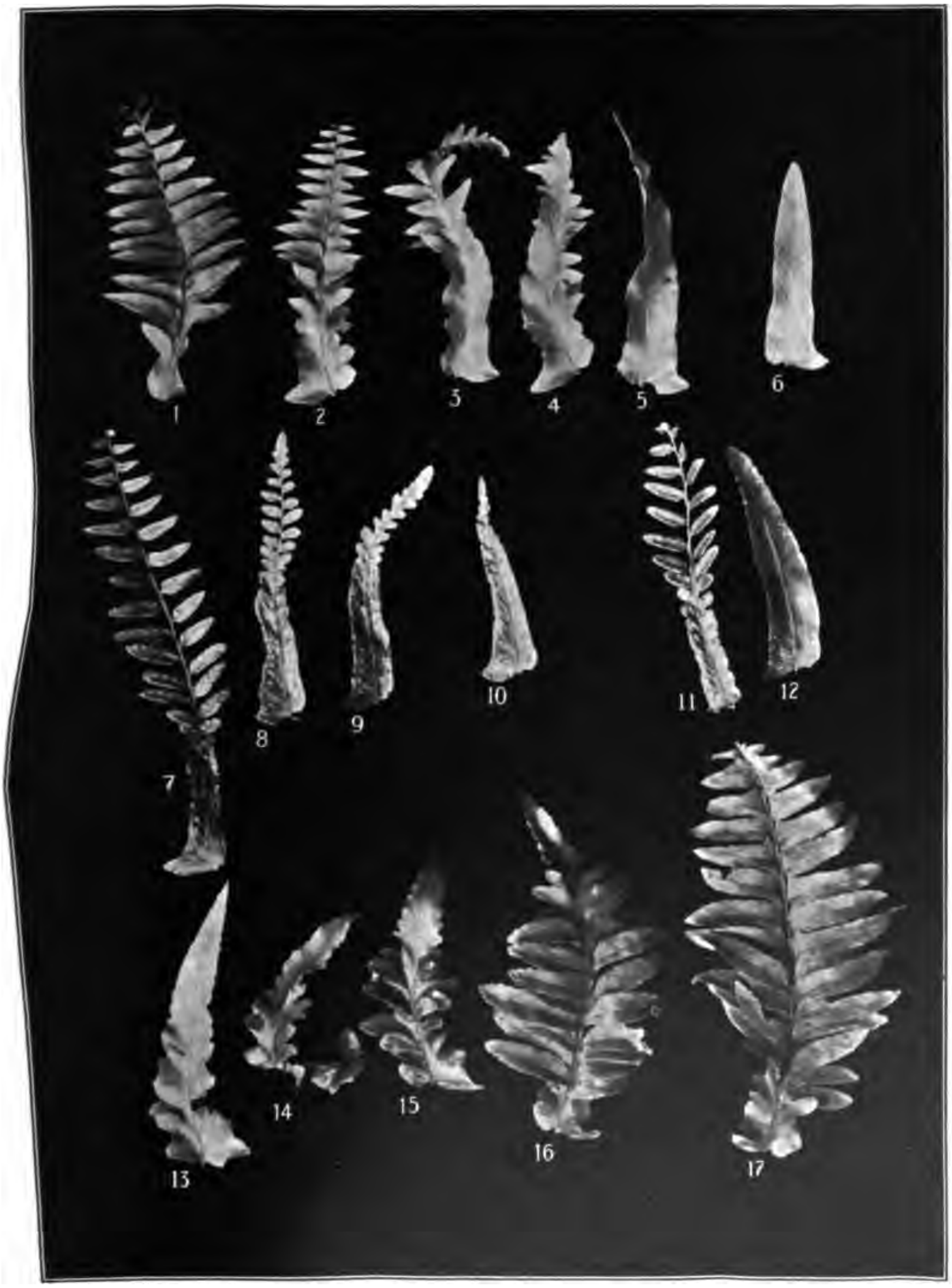
Fig. 2. From *elegantissima-compacta*, itself twice pinnate, pinnatifid.

Fig. 3. Also from *elegantissima-compacta*, but a distinct form.

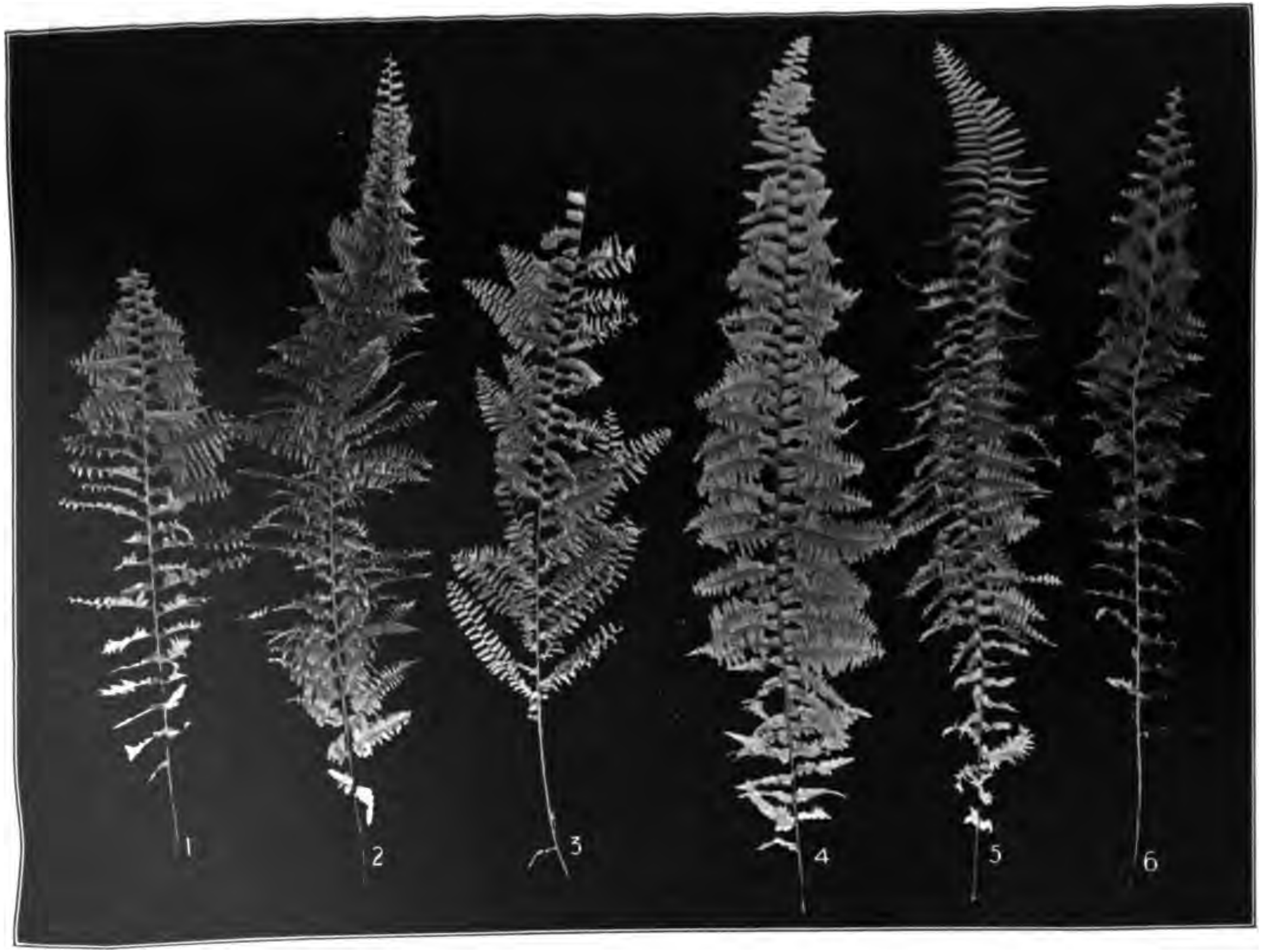
Fig. 4. From *superbissima*, a reversion in size (see also Plate VIII).

Fig. 5. *Robusta*, introduced by Robert Craig, Philadelphia; a reversion reported from *elegantissima*.

Fig. 6. Var. *fertilis*, possibly reversion from *Piersoni*.



BENEDICT: VARIETIES OF NEPHROLEPIS



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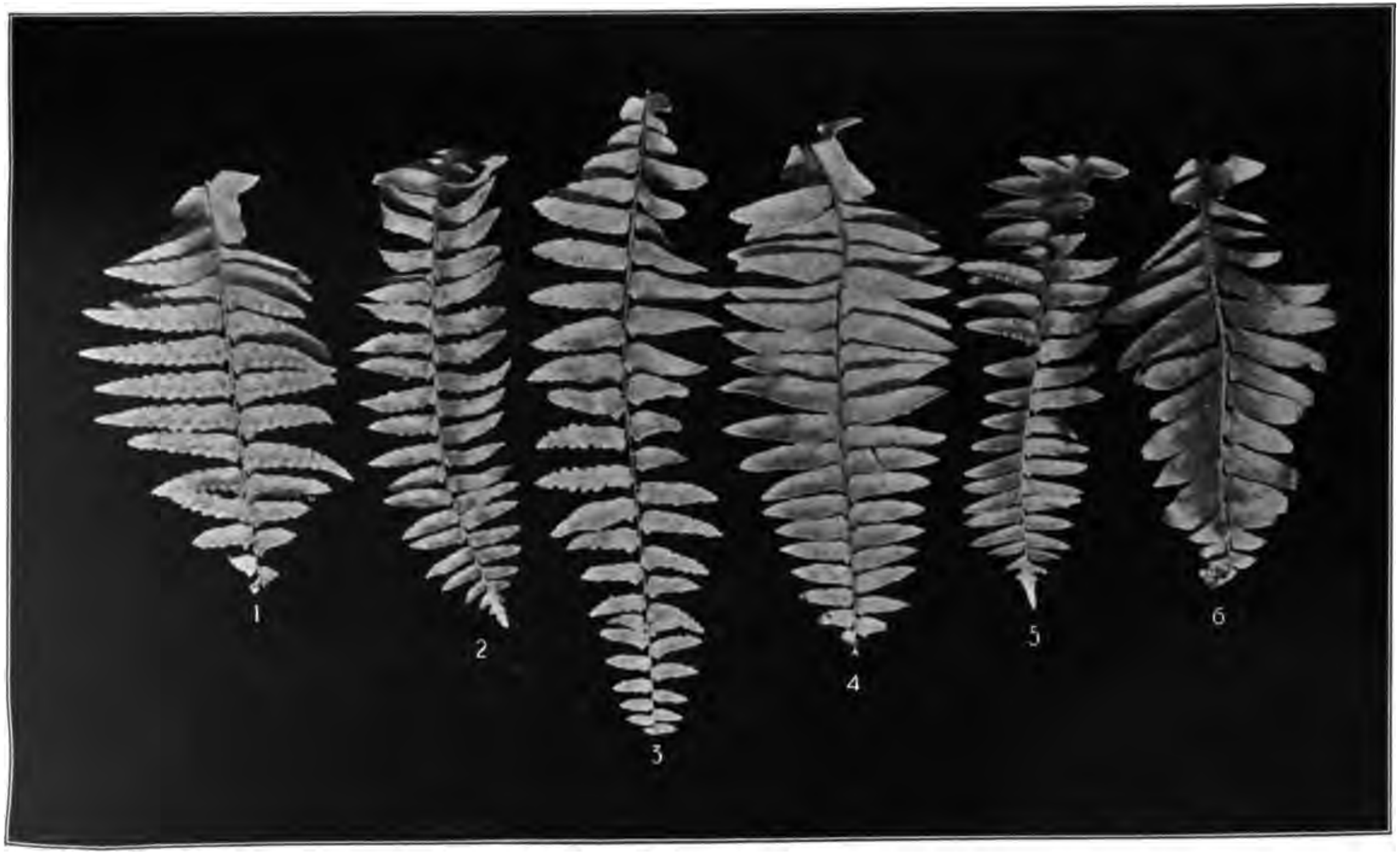

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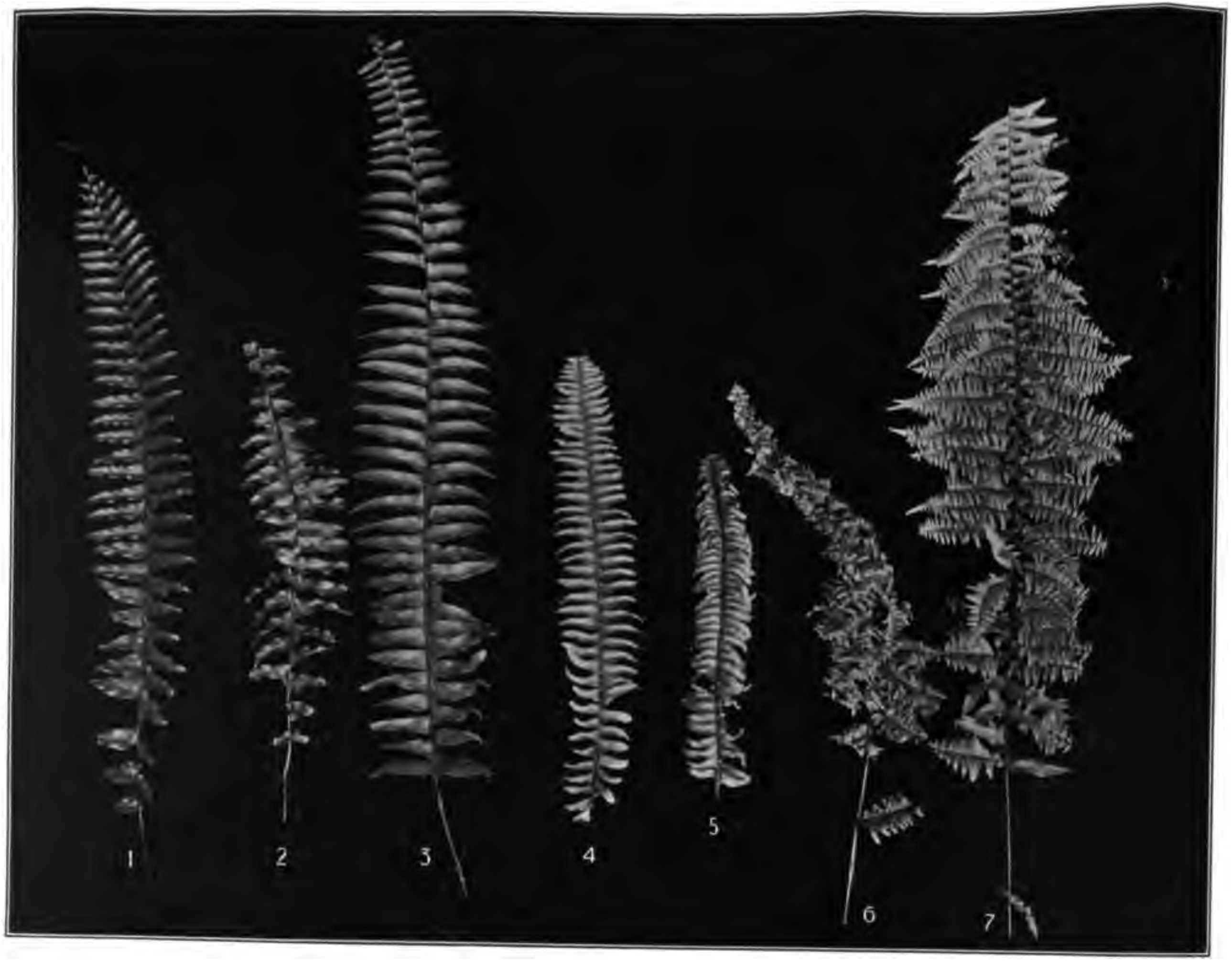

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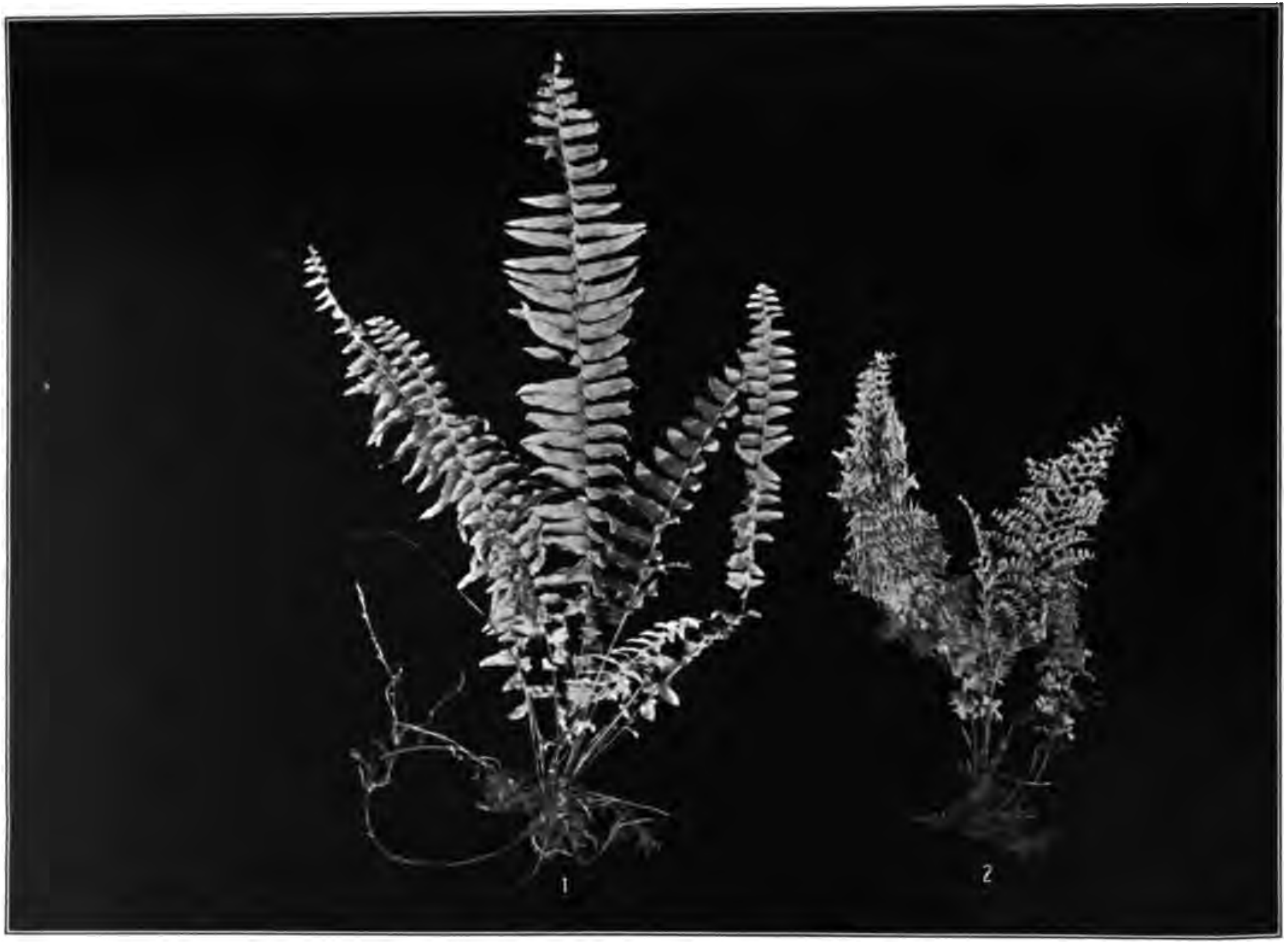
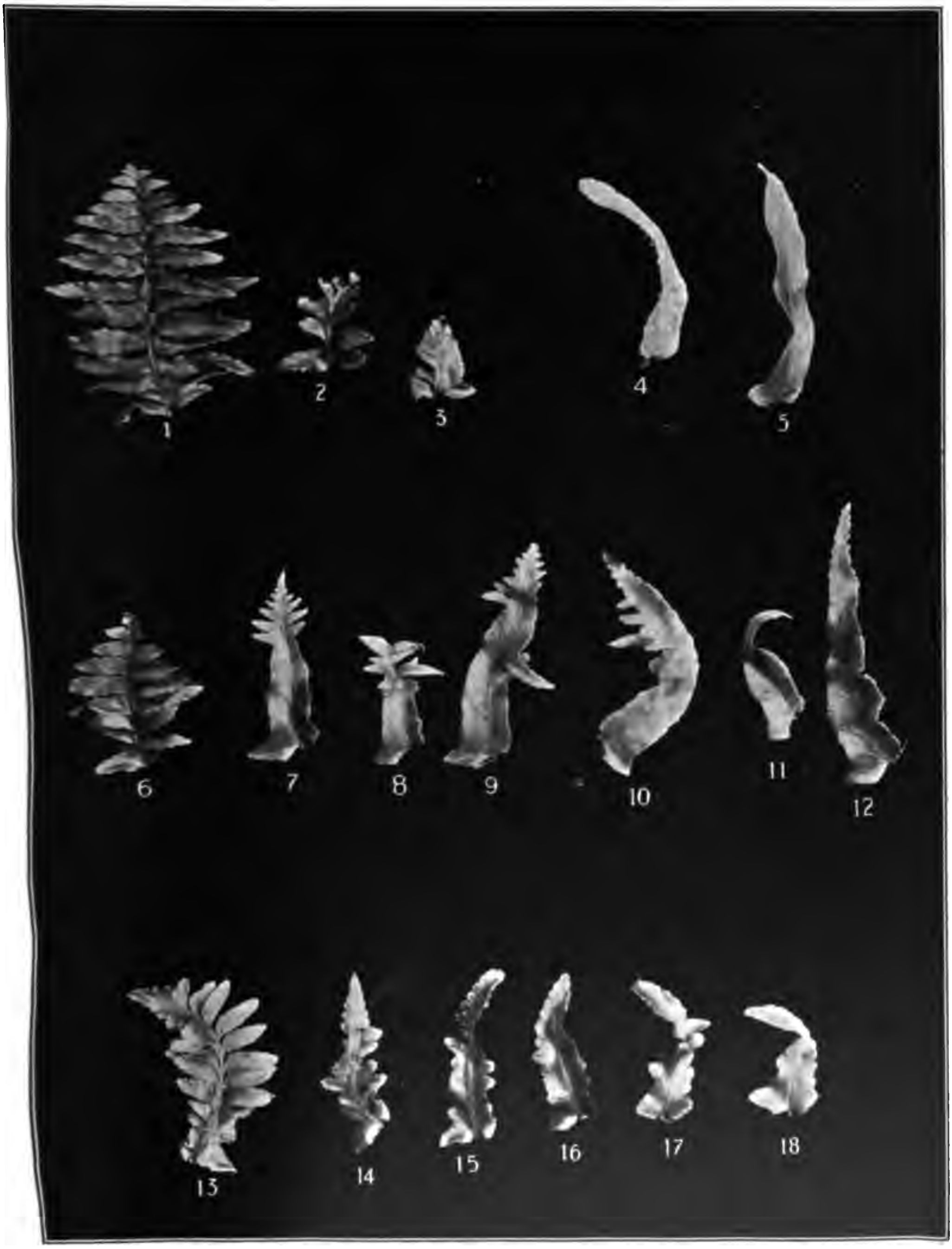


BENEDICT: VARIETIES OF NEPHROLEPIS



BENEDICT: VARIETIES OF NEPHROLEPIS

PLATE VII

Regressive mutations: pinnae of leaves shown in Plate VI.

FIGS. 1–6. Represent respectively the same forms as shown in Plate VI, figures 1–6.

PLATE VIII

Regressive mutations: leaves of forms showing reversion in size and in division.

FIG. 1. "*New York*" fern, a regressive mutation from *Giatrasi* (fig. 2), introduced by George Giatras, West Hoboken, N. J.

FIG. 2. *Giatrasi*, dwarf primary sport from *bostoniensis*.

FIG. 3. *Bostoniensis*, for comparison to show intermediate size of *New York* fern.

FIG. 4. Unnamed reversion, from dwarf once pinnate *viridissima* (fig. 5).

FIG. 5. *Viridissima*, introduced by F. R. Pierson, Tarrytown, derived by reversion in division from twice pinnate *superbissima* (fig. 6).

FIG. 6. *Superbissima*.

FIG. 7. Unnamed reversion in size, but not in division, from *superbissima*.

PLATE IX

Fluctuating reversion: bud plants showing unstable regressive variation.

FIGS. 1, 2. Sister plants of an unstable strain of *elegantissima-compacta*. FIG. 1, entirely once pinnate, except for a few pinnae on one or two leaves which show double division. FIG. 2, plant showing typical form of *elegantissima-compacta*.

PLATE X

Fluctuation and mutation of *elegantissima-compacta*.

FIGS. 1–3. Pinnae from one leaf of *elegantissima-compacta*.

FIG. 4. Pinna of "*Dwarf Boston*," introduced by F. R. Pierson as a stable reversion from *elegantissima-compacta*.

FIG. 5. Unnamed once pinnate mutation from *Wanamaker* (see figs. 13–18).

FIGS. 6-12. Pinnae selected to show range of fluctuation in an unstable strain of *elegantissima-compacta* (see figs. 1, 2, Pl. IX).

FIGS. 13-18. Pinnae selected to show range of fluctuation in *Wanamaker*, a regressive mutation of *elegantissima-compacta* introduced by Robert Craig, Philadelphia.

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CONTRIBUTIONS
No. 28

BOTANICAL EXPLORATION IN BOLIVIA

BY

ORLAND E. WHITE

BROOKLYN, N. Y.
1922

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BOTANICAL EXPLORATION IN BOLIVIA*

Bolivia—the land-locked republic of South America—is richly diverse in representatives of the three natural kingdoms—in minerals, in animals, and in plants, and especially in the latter. The wealth of its plant life as to number of kinds appears to have resulted, at least in part, from local differences in climate, as well as from striking physiographical variations and barriers. For Bolivia is a country of high stony plateaus, snow-capped mountains, deep V-shaped valleys, areas almost bordering on desert, tropical marshes, immense pampas, broad densely forested warm flat valleys, rain forests dripping with moisture from extremely frequent showers, dry, bromeliad-covered, hog-back mountain ridges and park-like areas where the herbaceous vegetation of the pampa (prairies) and the forests of the low-lying, flat river valleys come together—a region in which the trees and shrubs form clumps or islands in an ocean of grass, sedge, and other low-growing plants of the plains.

Crossing the country in an east and west line, one passes from the high plateaus from 11,000–13,000 ft. in altitude, supporting a comparatively dense population of Aymara and Quichua Indian farmers and herdsmen, to the relatively uninhabited tropical wildernesses of forest and pampa that constitute part of the watershed of the Amazon basin. On the plateaus barley, potatoes, and the English broad-bean (*Vicia faba*) thrive, while the forests of the lowland are rich in the familiar plant families of the American tropics.

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* Report to the Director of the Brooklyn Botanic Garden on the botanical work of the Mulford Expedition for the Biological Exploration of the Amazon Basin, June 1, 1921, to April 14, 1922. Brooklyn Botanic Garden *Contribution No. 28.*

During the spring of 1921 arrangements were made for the writer to conduct botanical investigations in Bolivia as the joint representative of the Brooklyn Botanic Garden and The Bussey Institution of Harvard University on The Mulford Biological Expedition. Under the leadership of Dr. H. H. Rusby, dean of the College of Pharmacy of Columbia University, the expedition planned to make biological collections, field studies, and explorations largely on the eastern flanks of the Andes in Bolivia, Brazil, and Colombia. Dr. Rusby has long made the Bolivian flora his special interest, having made several preceding journeys of botanical exploration to South America, crossing the continent through Bolivia in 1885. The area over which we hoped to work comprised that triangular region of the Amazon river system of which the apex is Manaos, and the two basal points, the headwaters of the Madeira river system in Bolivia and those of the Rio Negro in Brazil and Colombia. Originally we expected to spend fifteen months in this work, but, owing to numerous causes, we found it necessary to shorten our time to about ten and one half months, most of which was spent in Bolivia.

We sailed from New York on June 1, 1921, landed at Arica, Chile, on June 20, and arrived in La Paz, Bolivia, the next day, after a trying railroad journey of approximately 21 hours, during which an elevation of over 13,000 feet was attained. From La Paz our party proceeded by rail to Eucalyptus, where, through the courtesy of the Guggenheim Brothers, we were taken by automobile and mules to Pongo de Quime, one of their power stations on the eastern flank of the Andes, the magnificent road taking us through the "Pass of the Three Crosses" (Quimza Cruz) at an altitude of over 15,000 feet.

At Pongo our first serious collecting began, and we found it a botanist's paradise, as most of the plants were in bloom. At this altitude (10,000 feet) we were as yet too high for trees, but the long, narrow, deep valleys were rich in shrubs and herbaceous plants. Yellow calceolarias of two species were very common.

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Peperomias and epiphytic ferns were already much in evidence. Tuberous-rooted fuschias in flower peeked out here and there among the rocks overlooking the small stream. Clambering, vine-like composites (*Mutisia*) spread themselves over the low gray-leaved bush, their black and orange flowers reminding one somewhat of the Gazania daisy. Blue-flowered relatives of *Tradescantia* ("Wandering Jew") formed numerous populous colonies along the tiny Pongo river—here little more than a large brook. Selaginellas and Lycopodiums carpeted the damp rocks, two very curious species of the latter being collected. Far up on the dry mountain sides, spikes of bright, peculiar, blue-green-flowered relatives of our century plants made striking groups; and amid this diversity of color and strange perfumes hummingbirds darted and dived about.

From Pongo, where we were much indebted to the Guggenheim representatives in the persons of Mr. and Mrs. H. D. Johnson for a generous hospitality, we traveled by mules up and down cloud-capped, fog-and-rain-soaked mountains through a remarkably beautiful country—the Yungas. Our tons of baggage required several score of mules, and the mountain sides rang with the expletives of our muleteers as the picturesque winding mule train climbed and descended the narrow, rocky trails—trails that often outlined themselves against the steep mountain sides like the zig-zag path of a streak of lightning. And along these trails grew an everchanging profusion of plant life—six-foot fuschia bushes, scarlet with flowers; giant begonias; moss and bromeliad-covered bushes supporting here and there orchids with long sprays of yellow-brown-spotted flowers; deep purple-flowered melastomes (*Tibuchina*), almost as beautiful as our rhododendrons; alder trees on which scarlet-cerise-spiked bromeliads perched by the hundreds. And yet we were still high above the region of palms and monkeys, of rubber trees and Brazil nuts. But we were constantly descending. Each ridge we ascended and descended brought us nearer the tropic lowlands. We seemed to be always encountering the sleepy llama trains with oranges and lemons for the plateau cities, but we left them behind us as we descended below the 5,000-foot elevation.

In this Yungas country the finest coffee in the world is said to grow, and these narrow V-shaped valleys, with the little Aymara or Quichua Indian villages perched on their sides, are the home and center of the coca (cocaine plant) growing industry, bright green patches of which were bracketed here and there on the steep slopes, their orderly lines of bushes in striking contrast with the tangled and disorderly profusion and confusion of the general vegetation. Little orchards of cherimoya, cyphomandra, and arnotto trees clustered about the villages, while here and there patches of dwarf bananas gave a tropical effect to the landscape, even though palms were lacking. Wild tobacco (*Nicotiana Rusbyi*) and numerous other members of the potato family were common where the trail crossed the valley bottoms. Untamed raspberries clambered over the stony, grassy, low mountain tops, and beautiful Hippeastrums and other Amaryllids made bright spots of color among the ground ferns, as we descended to Cañamina on the 4,000-foot level. Here and at Espia, about 30 miles farther on, we made a stay of several weeks, waiting for balsa rafts to take us down the Bopi River, for Espia is the head of navigation on this route. During our stay at these points we were shown many courtesies by the superintendent of the Cañamina finca, Mr. L. Douillé, and his wife. Until our base camp was established at Espia we were much indebted to them for hospitality.

At Espia and Cañamina we made considerable collections, although the season was not the time of profuse bloom. The valley was rich in orchids, of both showy and inconspicuous-flowered species, but most of them had bloomed in May, at the end of the rainy season. So we saw largely plants in fruit and foliage—some of them magnificent clumps, recalling huge Boston ferns, as with their hanging leafy sprays they perched on the large limbs of trees. Giant cacti of the branched Cereus type were common—some of them over forty feet high. Peperomias, bromeliads, ferns, and several species of cacti shared roosting space on the trees with the orchid family. Bromeliads, in fact, were so common both as perchers and as ground plants that the almost leafless trees on many hillsides were gray with several species of them, while the mountain flanks were exclusively carpeted with them in considerable areas in some places. Perhaps the most striking element of the vegetation in this valley to me were the Erythrinas, sometimes called the hummingbird trees, because their flowers are supposed

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to be largely pollinated by these little bright-feathered visitors. Looking down the valley from the vantage point of a mountain flank, one saw amid the dark-green masses of vegetation dazzling spots of henna orange, where two or three giant Erythrina trees reared their domes of almost leafless branches, clothed with sprays of tango-hued flowers, while far up the dry mountain flanks the bromeliad-laden trees made great sweeps of Corot gray. Giant grasses (*Gynerium saccharoides*), related to the pampa grass, made canebrakes here and there along the Miguilla River, while in swampy places giant horsetails (*Equisetum*), an inch through and six feet high, made it easy to visualize the *Calamites* swamps of our ancient Carboniferous days. The dry, sandy, unshaded places in the river bed were covered with a thorny tangle of sensitive-plant bushes, 3–5 feet high, full of magenta flower clusters. Brushing through them, the leafy branches soon appeared almost bare and leafless, as also happens in the case of the little sensitive plant of our gardens (*Mimosa pudica*). In some places along this stream walnut trees (*Juglans boliviensis* ?) were said to be common, and a few nuts resembling our own black walnuts were picked up. Little green parroquets were almost as numerous in this valley as sparrows are here. I often saw their chattering flocks as I went about making collections.

At last the Moseteno Indians arrived from below with the balsa rafts, and we packed and made ready for the descent of the Bopi, Espia being just a bare spot at the head of the raft navigation where the La Paz and Miguilla rivers unite to form the Bopi. Our rafts were made of balsa logs—balsa being about as light as cork. And farther down, where the valleys were broader and the sandbars (*playas*) were more plentiful, these balsa trees (*Ochroma lagopus*) grow in great profusion, as do willows along our own plains' country streams. The rafts, of seven logs each, were lashed together two by two, and soon we had the rather thrilling experience (it reminded me of shooting the shoots or riding the giant racers at Coney Island, except one comes through soaking wet) of descending the snaky-winding, stony, rapid-encumbered Bopi. Four or five days of this found us at Huachi, a small hacienda—once a mission station—at the junction of the Bopi and Cochabamba rivers, which here form the Beni River, a large tributary of the Madeira River. And it was along the Rio Beni that we did most of our collecting. Our main bases on this stream were Huachi, Rurrenabaque, Rio Ivon, and Cachuela Esperanza, all in Bolivia.

At Huachi, through the courtesy of its owner, Don Elcides Mostaja, we were made comfortable in a large cane-sided, palm-thatched, dirt-floored house—the only kind commonly found in these parts. With this as a base, parties of us made collecting trips in balsas up the Cochabamba some 30 or 40 miles and back up the Bopi a considerable distance. About 18 miles up the Cochabamba River from Huachi lies the Franciscan mission (Covenda), with one priest and perhaps 150 Indians. The country is full of game, which considerably eased our supplies. From Covenda, a hard day's journey up a hog-back rocky ridge, lies the home of two interesting drug plants, known as *coto* and *para-coto* bark. Many worthless barks have been imported and sold in the United States in times past under these names, and the plants themselves from which *coto* and *para-coto* come remain as yet undescribed, only a fragmentary specimen of *coto* having been secured before. I was asked to make the trip up into the rain forest with Indians to secure a complete series of specimens, and fortunately we found *coto* in several fruiting stages and brought back a series of barks of *coto, para-coto,* and some of the related but worthless spurious forms, together with specimens. Another interesting tree of which we secured fruiting specimens is the *ajo-ajo,* or garlic-garlic tree, an enormous forest giant, often 5 feet through, the wood, leaves, and fruit of which have a strong onion or garlic odor, the source of which I have easily identified one eighth to one fourth of a mile away. Both "wild hogs" (peccaries) and fish crave the maple seed-like fruits of this tree—the one rooting among the falling leaves for them, the other nibbling them as they rest on the river surface. In both cases the meat is rendered unfit for eating.

At Huachi two young Bolivian scientists, representing their government, joined us, and the botanist, Señor Martin Cardenas, was extremely helpful to me in my work.

In the last days of September we were again on the move. This time our balsa rafts were headed down the Beni River to Rurrenabaque, a small village about five days distant from Huachi,

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situated at the base of the last foothills of the Bolivian Andes. The immediate country about this village is low and flat, except for the contiguous mountains to the southwest. The village itself lies at about 800 feet elevation. To the east and slightly north about 20 miles lies a park-like country of pampa and forest clumps, while still farther on one meets the pampa—a continuation of the Argentine pampa. To the northwest, about 80 miles, lies another stretch of pampa and park-like country, but this pampa region, although considerable in area, seems to be surrounded by forests.

To both these regions we made collecting expeditions—in the easterly direction about fifty miles to Lake Rogoagua, on the shores of which we camped and collected for about a month. The pampa country in its broad general aspect reminded me of our western prairies, though, of course, the plants were different. But the gnarled, twisted limbs and trunks of *Curatella Americana,* with its broad, rough leaves, easily passed, at a distance, for the scrub oaks of our plains. There were palms in groups here and there, though they were by no means a dominant note in the landscape. Ground orchids were plentiful and nine species were collected. A small species of *Zamia,* related to the more familiar "sago palm (*Cycas*), from the stems of which the Indians secure a starch, is common around the edges of the tree "islands." In the marshes one sees acres of a handsome yellow canna. Water lilies are common. Pools and ponds are often completely surfaced with floating *Salvinia* and the miniature fern-like *Azolla.* Water hyacinths (*Eichornia*) abound, as do also members of the arrowhead family. A few days farther north and east the *Victoria regia* occurs. On the drier uplands, grasses are said to be numerous, although the principal species I saw in bloom was probably *Sporobolus indicus.* Grasses of the genus *Andropogon* were not uncommon, especially in the park-like forest areas. In hard gumbo-clay areas, around patches of a papilionaceous thorn bush, portulacas and cacti of several species were in bloom. On the moist boggy banks of certain marshes one walked over carpets of a purple-flowered ally of our snapdragons. In the forest swamps arums and certain species of orchids were common.

Pampa transportation is by means of springless, grease-hungry, two-wheeled oxcarts, the huge solid wheels cut from a cross-section of a tree. And, as they move, each friction point tries to outdo the others in groans and creaks, while the drivers cry, "Utsa! Utsa!, Hi! hi!" or "he! he! he!" as the occasion warrants. Several dried oxhides serve as a bed or body to hold the baggage and keep it dry when a swamp or a creek is crossed. When the water gets too deep, these carts float and the oxen swim.

Through forests one travels with a motley caravan of half-naked, sweat-streaming, steaming barefoot Indian porters, each of which carries from 50 to 100 pounds. And it was in this manner that we journeyed to the other pampa region mentioned above, stopping at the Indian villages of Tumupassa and Ixiamas, the whole trip covering about three weeks. Along this forest trail the ground vegetation was largely a carpet of ferns and low-growing Acanthaceae with colored leaves, recalling some forms of coleus. On the flanks of some of the mountains were immense bamboo thickets. Among the more interesting forest trees were three or four fruit trees particularly worthy of note. Their Indian-Spanish names were *nui*, *camaruru*, *uva del monte*, and *durasno del monte*. The *nui* possibly is related to the cherries and is certainly one of the best wild fruits we found. When I once asked an Indian what the best fruit in these parts was, he answered immediately "El nui, señor." It reminds one of a small juicy plum, sparsely covered with small hairs, perhaps an eighth of an inch long. The single seed is about the size and form of a pistachio nut and the juicy pulp is a sprightly sweet or sub-acid. Both yellow and red fruited forms occur, but the red is the better flavored. The *camaruru* in season is often offered you on entering an Indian house as a sign of hospitality, and its deep yellow-papillated, sub-acid, gelatinous-fleshed fruits are very refreshing on a hot day, even though the two or three seeds are so large that but slight accommodation remains for flesh. *Uva del monte* means "grape of the forest," and the heart-shaped blue fruits with their sweet gelatinous flesh do remind one of grapes, though the tree they grow on is probably a relative of the elms and nettles. Along the path one day, as we traveled, one of our porters picked up a fuzzy-skinned fruit reminding me very much, as to size and shape, of a peach, and the native name is *durasno del monte*, Bolivian-Spanish

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for "peach of the forest." The flesh is said to be rich and like a mango, while its single seed tastes like a raw chestnut.

All through the Beni River valley chocolate grows wild, its big, ribbed, pumpkin-colored pods and purple seeds often furnishing a traveling Indian with a refreshing nibble—for these people are like children—they seem to be always eating. The great majority of the wild fruits are sweet, or sweet and oily; some of them have a flavor that reminds one forcibly of axle-grease. All the *genipas* come in this category, according to my experience. Sour fruits are not generally appreciated by the natives for any purpose except for sugared cooling drinks, such as limeade and "tamarindo." "It is good to eat, it is sweet, señor!" is the usual answer to a question as to a fruit's fitness for food. I told them about our grapefruit and they asked me why we planted it, since it was both bitter and sour. A fruit common about Rurrenabaque is the "bibi," a berry fruit with a single seed the size of a rice grain and with a flavor like wintergreen candy. Delicious! Ask the native children, who first called my attention to it! Another fruit much relished by the natives grows on a gorgeous blue-flowered tree, related to our verbenas, and the fruit, both as to size, shape, and flavor, reminds one of olives. In fact, the native name "aceitunilla" means "little olive."

From some standpoints this frontier is much blessed in the character of its plants, for no poison ivy or similar plant annoyer mars a walk through the undergrowth, except the palo santo tree with its stinging ants. And around these trees there is usually a small cleared space that warns one. The forests and pampas are full of valuable economic plants, so valuable to the native that he is able to satisfy most of his needs in the way of rope, soap, food, transportation, fuel, medicine, building material, and even jewelry and cigarette paper from the surrounding forest. For this is the native land of quinine, sarsaparilla, sululu, chicle of some types (the basis of chewing gum), rubber, Brazil nuts, copaiba, arnotto (our butter-color dye), indigo, tree cotton, kapok, and hosts of other raw products.

The Indian makes his bows from the black, tough-wooded *chonta palm,* and the string from the inner bark of a Bombacaceous tree. His arrows are pointed with this same bow wood; shafted from the flowering stalk of the giant cane (*Gynerium*); threaded with native tree-cotton, glued and waterproofed with chicle, and dyed almost any color with the numerous vegetable dyes. His wife desires a ring, whereupon another species of *chonta palm* furnishes him a black palm-nut, and he sits down on his doorstep or under a tree and makes his gift—a gift so unique and artistic that our own women may well envy the brown-skinned, barefoot possessors.

About the first of February we left Rurrenabaque and made a new base under the hospitable roof of the Suarez Brothers' finca at Rio Ivon. Mr. Hansen, the superintendent, gave us every facility possible for our work and through him we were able to spend about a week collecting along the Ivon River in a covered boat. At this base we first came into intimate contact with the rubber country, although we did see rubber collecting on a small scale as far up the Beni as a day or so below Rurrenabaque. Here, too, we first saw the Brazil nut tree at home.

The first two weeks in March found us still farther down the Beni, this time at Cachuela Esperanza, the main depot and headquarters of the Suarez Brothers, to whom we were again indebted in many ways. Don Nicolas Suarez, the head of the firm, as well as his employees, took a personal interest in our work and showed us many courtesies.

It was here that I first secured the definite information concerning *Caapi* or *ayawasca* that eventually led to my securing a small supply. *Ayawasca,* or *aya-huasca,* as it is called on the lower Beni, is a vine 30 to 40 feet or more high, first described by Richard Spruce in 1853 under the name *Banisteria Caapi* Spruce. He found it common, both wild and cultivated (that is, planted in the mandioca patches), on the upper tributaries of the Rio Negro, perhaps 1,500 miles at least from the region where I secured it. According to the information I obtained from the natives, the vine is not milky-juiced, grows to grand proportions, has greenish-white flowers, large leaves, and blooms in April. The cinnamon-colored, woody, "elbow-knotted" stem is the part generally used, though I was assured several times that every part of the plant could be utilized with effectiveness. Leaves of a small tree or shrub with cranberry-like, reddish-yellow fruits, called *chaco* by

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some and *guayavoche* and *cagua* by others (though I am not certain that the two latter names refer to the same plant as *chaco*), are used in preparing the *ayawasca* beverage. Different plants may be used, and I obtained no specimens under the name of *guayavoche* and *cagua*. According to some of my informants, the *ayawasca* is often used alone and this checks up with Spruce's account. In preparing the drink, pounded pieces of the vine *ayawasca* are put in a pot on top of a layer of *chaco* leaves, then another layer of *chaco* leaves, then *ayawasca*, and so on until the pot is full. Water is added and the whole boiled until the liquor is the color of wine. As much as a quart may be taken by one person at a time, if one is used to taking it. The decoction thus made is said to last for a long time when bottled, and is sold for diversion purposes at the fiestas of some of the Peruvian Indians that have come into this part of the country as rubber collectors. The dried stems of the vine are also said to retain their power for at least a year, but the value of the *chaco* leaves vanishes on drying.

Long before I obtained actual specimens, I heard numerous stories about what tribes used it—usually they were distant ones—and definite data were quite difficult to obtain until I reached this place, where, through a Spanish-Indian helper, I was enabled to secure specimens of the vine and what I believe to be fairly accurate information concerning its habitat, rarity, characteristics, preparation, and effect. My information differs in detail from Spruce's account, but in general they check each other. Of course, I did not see any ceremonial usages and I doubt if these people now use it with much of the ancient form. So far as I could gather, they take it for its weird effect, just as some people use whiskey. When I first heard of it, I surmised it might be *hasheesh*, as part of the effect appears to be similar. The effect from drinking *ayawasca* comes with rather amazing rapidity—Spruce says two minutes—and they told me it was *very soon*. The first phase, in general, is a state of courageous drunkenness, though at the very first the Indian turns pale, and there is much trembling. Suddenly he perspires, dances with wild and reckless abandon, and has a boastful, courageous fit, in which he rushes about inflicting violent blows and boasting of what he would do to his enemies, though his blows may fall on his friends in the absence of enemies, Spruce says this lasts ten minutes, though from what I heard the time must vary with the amount taken and with the individual. Succeeding this phase one grows calm, drowsy, and exhausted; a sleep ensues, during the forepart of which wonderful mirage-like visions of beauty—regular Arabian Nights' pictures—pass before one, panoramic fashion, gorgeous, magnificent sights resurrected and composed of all one has ever thought, read of, or experienced. Finally, this is succeeded by a sojourn comparable to that of sinners depicted in Dore's illustrations in Dante's Inferno. An educated Ecuadorian, cited by Spruce, describes the effect on himself as first that of an aerial voyage through charming landscapes, great cities, lofty towers, beautiful parks, etc. Then "I found myself deserted in a forest and attacked by beasts of prey, against which I tried to defend myself." According to the natives I talked with, one sees beautiful lakes, gorgeous tropical scenery, and, when the wild-beast stage comes on, they again are in a fighting, courageous phase.

In some parts of Brazil and Ecuador in former times, and maybe yet among the but slightly civilized tribes of the upper tributaries of the Rio Negro, the drinking of *ayawasca* was attended by much ceremony. Women were not allowed its use on pain of death, and no boy took it until he had reached "manhood." Medicine men used it for divination purposes—to discover enemy plans, unfaithful wives, and who had bewitched a sick man. Spruce sent specimens to Kew, but apparently nothing has ever been done with them toward discovering the active principle. After the three phases mentioned above, a deep sleep ensues, and I was assured time and again that one awoke usually with no harmful after-effects. Others have told me that, under some conditions, vomiting and diarrhoea may be brought on. Arrangements have been made for obtaining a larger supply of *ayawasca* and, through Dr. Rusby, work for the determination of the active principle will be started.

On March 15, Dr. Mann, Mr. Pearson, and myself left Cachuela for New York, where we arrived April 14. On our journey home we made excellent connections by way of launches, the Madeira-Mamore R.R., the steamer "Tupy" of the Amazon Navigation Co. to Manaos, Brazil, and from there down the Amazon to Para and direct to New York by the Booth line S. S. "Justin."

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The joint collections of the botanical contingent of the expedition will number about 13,000 specimens, representing over 2,000 species, many of which are native economic plants. Over 100 species of orchids (dried specimens) and seeds of about 200 species of herbs, trees, and shrubs were collected. In addition to these, many kinds of wild fruits were brought back in formaldehyde solution in two quart jars. An attempt was also made to secure exhibits illustrating the native uses of Bolivian wild plants. The writer was especially interested in the primitive agriculture and customs of the Indian tribes of the Beni region, and notes were taken and information collected with the idea of publishing a paper on this subject. Much photographic material was also secured.

Upon Dr. Rusby's leaving us in December because of ill health, I had charge of the botanical work of the expedition. The Bolivian government, through its president and various other officials, showed us innumerable courtesies, and we were also much indebted to the American representatives of the consular and diplomatic services in Chile, Bolivia, and Brazil.

ORLAND E. WHITE.

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CONTRIBUTIONS
No. 29

ANTHRACNOSE OF THE BOSTON FERN

BY

JAMES A. FARIS

BROOKLYN, N. Y.
1923

Reprinted without change of paging, from MYCOLOGIA
15 : 89–95, March, 1923

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ANTHRACNOSE OF THE BOSTON FERN[1]

JAMES A. FARIS

(WITH PLATES 8 AND 9)

The Boston fern (*Nephrolepis exaltata* (L.) Schott.) is a house plant very widely grown for ornamental purposes, and because of its merited popularity as an indoor plant its culture constitutes one of the valuable branches of the florist trade. The unusual freedom from disease of these ferns under indoor conditions contributes largely, no doubt, to their wide cultivation.

In the extensive fern collection of Dr. R. C. Benedict at the Brooklyn Botanic Garden, where he is experimenting upon the origin of new varieties of *Nephrolepis* (2, 3), some plants have become attacked by an anthracnose disease. This condition was first noticed by Dr. Benedict in 1919 and seemed to be confined to certain sporeling strains then under observation. Although serious injury was confined to a few individuals, these infected plants continued to have diseased fronds season after season. A planting of sporelings set out for bed-culture in the fall of 1921 were so seriously diseased that they made little growth, each new leaf being killed at its growing tip soon after it began to unroll. Such plants showed a mass of dead and withered stumps of fronds with here and there a straggling leaf which had escaped death, but always showing the anthracnose lesions.

SYMPTOMS OF THE DISEASE

The disease first appears upon the growing tips of the fronds and upon other succulent leaf-tissue which has not become hardened. The lower parts of the fronds sometimes show typical anthracnose lesions; but the writer's observations have been that the infection in these cases has always taken place before the tissue has become hardened and woody.

The first appearance of the disease is indicated by a slight browning of the infected tissue. This becomes apparent in inoculations from pure cultures about forty-eight hours after spraying the inoculum upon uninjured, vigorously growing fronds. The brown spotting involves only a few of the epidermal cells at first, but rapidly spreads longitudinally and around the midrib and petiole of the frond, finally involving the young pinnae. Attacked tissues shrink rapidly, presenting an appearance such as is shown in figure 1 at the end of the fifth day after inoculation.

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[1] Brooklyn Botanic Garden Contributions No. 29.

When the plant is kept under humid conditions, small white patches begin to appear over the surface of the brownish lesions within a few days, but these white masses of conidia do not become apparent except under conditions of high humidity. Seldom does the canker appear over the entire frond, but two or three separate lesions on the same frond are not uncommon. The infection of the older fronds is limited to the young parenchymatous tissues near the apex of the leaves. A considerable area of the leaf may become infected in this way, as is shown in figure 2, which is a photograph of four older leaves inoculated with pure cultures of the organism at varying distances behind the unrolling tip. The inoculation was made at one inch behind the tip in *A*, two inches behind in *B*, three inches behind in *C*, and four inches behind in *D*. Inoculations farther back upon the maturer leaves gave no infection.

In exceptional cases, where the lower part is attacked, the unrolling tip may continue growth for a time. It is short-lived, however, and eventually withers, shrivels, turns brown and finally almost black. Attacks on older tissues by the fungus may result in a limited canker being produced. As a whole, susceptible ferns present a blighted, sickly appearance with their numerous dead fronds far outnumbering the isolated, partially diseased ones which have been able to develop a few pinnae.

THE CAUSAL ORGANISM

Isolation.—Small pieces of diseased fronds about ½ cm. in length were immersed for five minutes in corrosive sublimate solution (1 : 1000), rinsed in distilled water, and then plated in potato agar slightly acidulated with a 5 per cent. solution of lactic acid. These plates were kept in the incubator at 20° C. Within forty-eight hours mycelium began to grow out from the pieces of host

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tissue. By the fourth day appressoria were abundant, and at the end of a week masses of spores formed within the surface mat of mycelium. A few such cultures were pure and from these, conidia were transferred to fresh dishes. Within one month perithecia began to form, and by the end of the seventh week the plates were literally covered with them. (Fig. 3.)

The growth of the fungus.—The fungus grows slowly on potato agar and the extension of the colony is rather limited. It grows more rapidly on corn-meal agar made up by the formula given by Shear and Wood (4). On corn-meal agar the plates were covered and perithecia formed within five weeks. When two or more colonies are growing in the same dish the mycelia do not intermingle, but check growth as the edges of the colonies approach each other, causing a surface piling up and leaving a definite margin between the colonies. (See fig. 3.)

There is no noticeable increase in the number of perithecia formed at the margins of these colonies, however.

MORPHOLOGY AND PHYSIOLOGY OF THE FUNGUS

The imperfect stage.—In the imperfect stage this fungus is of the typical *Colletotrichum* type, producing setae around the acervulus. The one-celled spores are produced abnormally in acervuli, both in culture-media and on the diseased fronds. There is a gelatinous matrix around the spores which holds them together when dry, but dissolves readily in water, permitting their spread as in the case of the anthracnose of the bean (1). The acervuli on the host are innate, erumpent, discoid, surrounded by long, black setae six to twelve in number; conidia tetrete to fusoid, 4–6½ x 12–18μ; conidiophores rather short, straight, seldom curved, usually bluntly rounded at the tips. Germination usually begins by the formation of a septum in the conidium, followed by the protrusion of a germ tube from either the side or end. This tube usually grows a short distance and then forms an appressorium from which further growth may take place. These appressoria are subglobose, flattened on one side, and have dark-colored thick walls containing dense granular cytoplasm. Typical conidia from artificially infected fronds of the Boston fern are shown in figure 4. Setae at the edge of the acervulus are also shown.

The ascogenous stage.—The ascogenous stage has never been found upon diseased ferns by the writer. The perithecia in cultures assume a variety of forms according to whether they are produced in groups or singly (fig. 5). When produced singly they are membranous, dark-brown to almost black, with a lighter-colored beak at the apex, flask-shaped, sparingly hairy, and immersed in the medium. The asci are sessile, fusoid, 8–12 x 68–120 μ. Spores hyaline, granular, fusiform, 1-celled, and 4–6 x 13–16 μ. Paraphyses none. (See fig. 6.)

The ascospores germinate readily in a manner very similar to the conidia by producing one or more germ tubes which develop appressoria and mycelium.

NAME OF THE ORGANISM

The spore measurements for both conidia and ascospores average rather low for species of *Glomerella* as given by Shear and Wood (4), but are well within the limits of those given for *Glomerella cingulata.*

In order to determine whether the organism in hand would infect hosts readily attacked by *G. cingulata,* transfers from pure cultures were made in the first case to the fruit of the apple. This test was repeated eight times upon as many different varieties of apples and in no case did any infection occur.

Similar tests were also tried upon the green pods of the bean, *Phaseolus vulgaris,* and upon the fruits of the banana and cucumber, with the like result that no infection occurred. While no inoculations were made upon cotton, this fungus would seem to differ from *Glomerella gossypii,* which is described as having paraphyses.

The failure of cross-inoculation experiments, together with the growth characteristics of this organism, would seem to justify according it specific rank and it is tentatively named **Glomerella Nephrolepis** sp. nov.

RELATION OF THE FUNGUS TO THE HOST

When either ascospores or conidia germinate upon a susceptible plant of the Boston fern, they produce appressoria and in turn fine hyphae which penetrate the cuticular and subcuticular layers and

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produce a vesicle from which branches arise and extend into the host tissue. The invading hyphae enter the host cells, causing their collapse. The growth of the hyphae through the young tender tissue is very rapid and can be followed by the browning of the host cells soon after attacked. The walls collapse and the lesions become conspicuous within a few days, as is well shown in figure 1.

At about the time the cankered areas form the mycelium begins to develop abundantly in the epidermal cells and those just beneath, forming a stroma of closely crowded and septate hyphae. The host cells at this time are badly disorganized and the individual cells are difficult to observe. From the pseudoparenchymatous tissue thus formed arise short conidiophores, at the apex of which are borne the bluntly rounded conidia. These are produced in such abundance that they soon rupture the cuticle and are freed. (See fig. 4.) The lesions produce the acervuli at the center first and farther out as the canker enlarges. Long, brown, 4–5-septate setae are produced around the margin of the acervulus, both on the host and in cultures. They are almost the same diameter throughout, tapering bluntly to a point at the free end. The setae are few (6–12) in number and on the host about 6μ in diameter and 120–200μ in length.

PROOF OF PARASITISM

From pure cultures secured as heretofore described both conidia and ascospore subcultures were made. Spores from both types of cultures were sprayed upon healthy fern plants, incubated under bell jars, and typical lesions were produced. From these lesions isolations were again made and the cycle repeated five times. In every case typical diseased fronds were produced, and cultures made from all cycles have consistently shown the same cultural characteristics.

VARIATIONS IN SUSCEPTIBILITY

In regard to differences exhibited by the various strains of the Boston fern to the attack of the fungus, Dr. Benedict, in a letter to the writer, makes the following note: "In one number, 315, this blighting affected a portion of the leaves regularly. The variety was tested to see whether perfect leaves might be produced under the best conditions, but without success. Grown in poor conditions, almost all the leaves would stop growing when about one third the length typical for the form had been reached. None of the other sporelings tested out at the same time showed the same defect. Later, in another batch of plants of the same sowing, a similar diseased condition was noted in at least three numbers, 75–5, 75–11, 75–14. . . . All except the three numbers mentioned above made vigorous, healthy growth, but these showed the leaf-blighting both in stock cultures and in those in the pots. There are indications of occasional blighting of single leaves in other numbers, but these four above are the ones which show a continuous affected condition."

ECOLOGIC ASPECTS AND CONTROL

The spread and maintenance of the disease are fostered by a crowding of the plants on the benches and in the propagating houses, by overhead watering, where the water remains on the leaves for long periods of time, and by high humidity and temperature. Spread of the disease in the greenhouse is primarily through close planting or crowding and watering.

Tests, where slightly infected plants were pruned of all diseased leaves, the soil covered with a coating of sand and water applied only to the soil, have demonstrated that slightly susceptible forms may be rid of the disease by these measures.

The following control measures have been found effective:

1. Selection of resistant forms. Variation in susceptibility points the way to control by this means.
2. Proper aëration of the greenhouse to keep a low relative humidity.
3. Watering the soil in the pots and benches, care being taken to dry the leaves after washing them.
4. Removal of all infected tissue as it appears and destruction of badly diseased plants.

The writer is indebted to Dr. R. C. Benedict for an abundant supply of host material.

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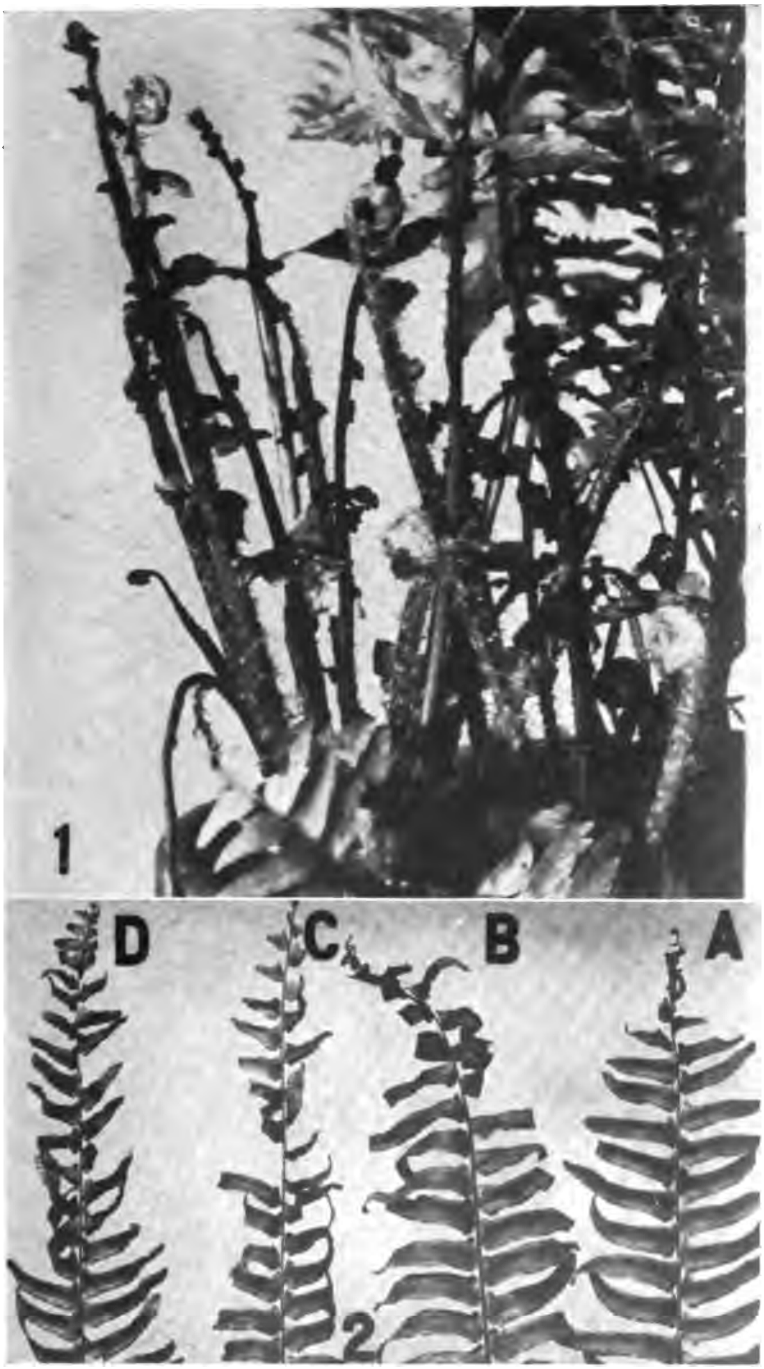
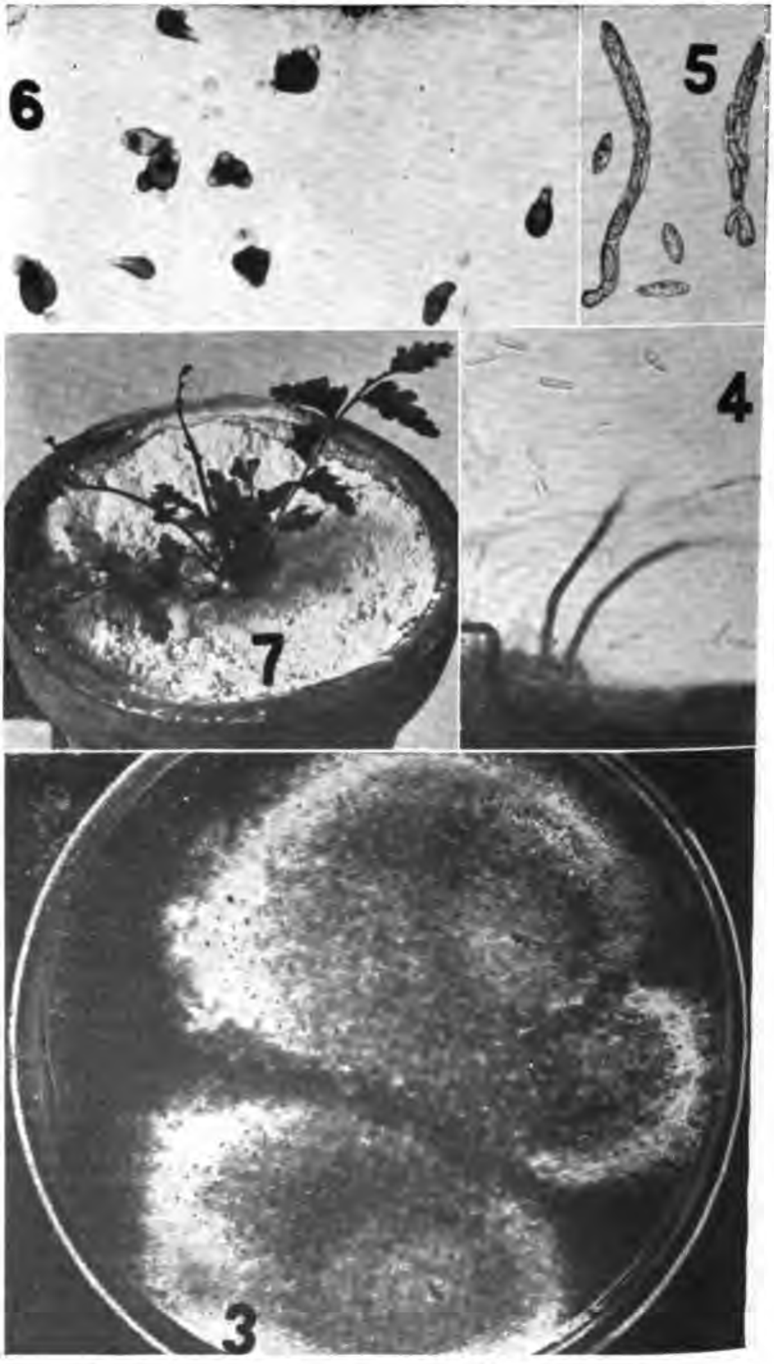


BOSTON FERN INOCULATED WITH GLOMERELLA NEPHROLEPSIS FARIS



CULTURES AND SPORES OF GLOMERELLA NEPHROLEPIS FARIS

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EXPLANATION OF PLATES

PLATE 8

Fig. 1. Young fronds of Boston fern five days after inoculation from pure cultures of the anthracnose organism. Reduced.

Fig. 2. The tips of four fronds inoculated at varying distances from the terminal growing point. Reduced.

A. Inoculated 1 inch behind the tip.
B. Inoculated 2 inches behind the tip.
C. Inoculated 3 inches behind the tip.
D. Inoculated 4 inches behind the tip.

PLATE 9

Fig. 3. Petri dish cultures seven weeks old showing growth habits of the anthracnose fungus upon potato agar.

Fig. 4. Microphotograph of conidia and setae of the *Colletotrichum* stage.

Fig. 5. Camera lucida drawing of asci and ascospores. × 375.

Fig. 6. Microphotograph of various forms of perithecia produced in agar cultures.

Fig. 7. Typical attack on a young sporeling. Normal size.

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CONTRIBUTIONS
No. 30

Varietal Resistance and Susceptibility of Sorghums to Sphacelotheca Sorghi (Link) Clinton and Sphacelotheca Cruenta (Kühn) Potter

BY

GEORGE M. REED

BROOKLYN, N. Y.
1923

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VARIETAL RESISTANCE AND SUSCEPTIBILITY OF SORGHUMS TO SPHACELOTHECA SORGHI (LINK) CLINTON AND SPHACELOTHECA CRUENTA (KÜHN) POTTER[1]

GEORGE M. REED

(WITH PLATES 14 AND 15)

Very extensive investigations on the resistance and susceptibility of varieties of sorghum (*Holcus Sorghum* L.) to the covered kernel-smut (*Sphacelotheca Sorghi* (Link) Clinton) have been carried out.[2] Practically all of the varieties of sorghums, many of which were represented by a number of different strains obtained from various sources, were grown.

As a result of these investigations it was found that the strains and varieties of broom corn, kafir, shallu, and sorgo were quite susceptible to the covered kernel-smut, giving relatively high percentages of infection. Two varieties of durra, the common Brown and White durra, also proved highly susceptible. However, in recent years a number of introductions of White durra have been made and some of these have shown a high degree of resistance. The kaoliangs, as a group, were only moderately susceptible; a few varieties like Barchet, Blackhull, Manchu Brown, and Valley kaoliang gave relatively high percentages of infection; on the other hand, Dwarf Brown kaoliang has consistently proved to be resistant. All varieties and strains of milo and feterita have shown very marked freedom from infection. Several miscellaneous sorghums were also grown and some, for example, Schrock kafir and

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[1] Brooklyn Botanic Garden Contributions No. 30.

[2] These results, which have been written up by the author in coöperation with Professor L. E. Melchers, are based upon experiments conducted at Columbia, Mo. (4 years); Manhattan, Kan. (6 years); Amarillo, Tex. (4 years); Arlington Experiment Farm, Va. (2 years); and Brooklyn, N. Y. (2 years). The manuscript has been submitted for publication as a Bulletin of the U. S. Dept. Agr.

Freed sorgo, were infected to a greater or less extent. Others, as Darso, Dwarf Hegari, Kafirita, and Sudan corn, gave negative results.

Observations on the head-smut (*Sorosporium Reilianum* (Kühn) McAlpine) of sorghum were also made at Amarillo, Texas, where soil infestation appears to be prevalent. No infections of broom corn, feterita, and milo were observed. A low percentage of infection occurred in several varieties of kafir and kaoliang, and somewhat higher percentages of infection in certain varieties of sorgo. However, only eight varieties of sorghum showed conspicuous susceptibility to the head-smut: Brown durra (*S. P. I. 17537*); White durra (*S. P. I. 17535*); Black Amber sorgo (*S. P. I. 32384*); Minnesoto Amber sorgo (*F. C. I. 01950*); Red Amber sorgo (*S. P. I. 1534* and *17548*); Coleman sorgo; Early Rose sorgo; and Schrock kafir.

Potter (27) and Kulkarni (20) have recorded some results with the loose kernel-smut (*Sphacelotheca cruenta* (Kühn) Potter). Potter reported that he was unable to infect milo with this smut, but with some other sorghums he obtained the following percentages of infection: Amber sorgo, 10.9 per cent; Freed sorgo, 5 per cent; broom corn, 6.9 per cent; kafir, 13.8 per cent; and kaoliang, 10.3 per cent.

Kulkarni (20) inoculated seed of Dwarf milo with the spores of both covered and loose smut and planted it at the Agricultural College Farm, Poona, India. Apparently the same lot of seed was inoculated with the spores of both smuts. He obtained a total of 645 heads, of which three were infected by *Sphacelotheca sorghi* (.47 per cent infection) and fifty by *S. cruenta* (7.8 per cent infection). The three plants infected by *S. Sorghi* may have been some other sorghum which was accidentally present in the plot. It is a question, however, whether the results with *S. cruenta* can be thus explained.

The writer has continued his investigations on the behavior of sorghum varieties to covered kernel-smut (*Sphacelotheca Sorghi* (Link) Clinton) and, in addition, has carried out a series of experiments with the loose kernel-smut (*S. cruenta* (Kühn) Potter).

Sphacelotheca Sorghi is a typical kernel-smut, the individual

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ovaries of the flowers being involved and converted into false kernels, or smut balls. It is unquestionably the most widely distributed and destructive smut which attacks sorghums and is probably to be found wherever these plants are grown. It was first described, from a specimen collected in Egypt, by Link (23) in 1825. Since then it has been recorded by a large number of observers. Barber (2), Kulkarni (19), and Butler (10) note its prevalence in various parts of India, where it is a destructive disease of sorghums in the Madras Presidency, Bombay Presidency, the Central Provinces, and Burma. A large number of seed lots of Chinese kaoliangs have been imported into the United States and Ball (1) states that most of them were contaminated with the spores of this smut. This indicates its prevalence in those parts of China where kaoliangs are grown. Miura (25) mentions its occurrence in Manchuria; Bubák (6) and Thomas (31) in Mesopotamia; Busse (9) in Tanganyika Territory (formerly German East Africa); Snowden (30) in Uganda; Evans (13) in South Africa, especially on kafirs; McAlpine (24) in Australia; Hauman and Parodi (15) in Argentina. It has also been recorded in lists of smuts collected in different parts of Europe: by Winter (34) in Germany, Schröter (29) in Silesia, Lind (21) in Denmark, Lindau (22) in the Mark Brandenburg, Bubák (7) in Bohemia, Prillieux (28) in France, and Passerini (26) in Italy. The first record of its occurrence in the United States was made by Burrill (8) in 1888. It was reported by Webber (33) in Nebraska in 1889, and by Failyer and Willard (14) in Kansas in 1890. In 1906 Clinton (12) recorded its occurrence in thirteen states, as well as in Ontario, Canada, Jamaica, and Cuba.

Sphacelotheca cruenta was first described by Kühn (17) in 1872. It has been recorded by Winter (34) in Germany; Schröter (29) in Silesia; Bubák (7) in Bohemia; Busse (9) in Tanganyika Territory; Kulkarni (19) in the Sholapur District of the Bombay Presidency; and Butler (10) in the Central Provinces. It was first collected in the United States by Trelease (32) at Madison, Wisc., who, however, incorrectly recorded it as *Sphacelotheca Sorghi*. According to Potter (27) it has been introduced into the United States on seeds of kaoliangs from various parts of China. Its presence in Australia or South Africa has not been noted.

According to the investigations of Kühn (18), Brefeld (3, 4, 5), Clinton (11), Kellerman (16), Butler (10), Kulkarni (19), and others, the two kernel-smuts have a very similar life-history. The infection takes place in the early germination stages of the seedlings and usually from spores adhering to the seed. After penetration of the germ-tube, the young mycelium develops in the embryonic tissue of the host, keeping pace with the latter's development. At the flowering period the ovaries and adjacent parts of the host are converted into the characteristic smut balls. The pathological differences between the two smuts are quite striking and are described below. The spores, however, are very similar in shape and size and germinate in a similar fashion.

The seed of the varieties of sorghum was obtained from a number of different sources. Some of it was secured from seedsmen, but many of the samples were obtained from the Agricultural Experiment Stations of Missouri, Louisiana, Kansas, Oklahoma, and Texas. The writer is especially indebted to Dr. C. R. Ball and Mr. B. E. Rothgeb, Office of Cereal Investigations, and Mr. H. N. Vinall, Office of Forage Crop Investigations, U. S. Department of Agriculture, for the seed of a large number of varieties.

The spores of *Sphacelotheca Sorghi* used for inoculation were collected on kafir, grown in experimental work the previous season. The spores of *Sphacelotheca cruenta* were obtained through the courtesy of Mr. S. L. Ajreker, Poona Agricultural College, Poona, India.

Sufficient seed for planting the rows was placed in separate packets and one set of the varieties was inoculated by dusting heavily with the spores of *Sphacelotheca Sorghi*, and the other set inoculated in the same fashion with the spores of *S. cruenta*. Special care was taken not to mix the two smuts either during the operation of inoculation or subsequent planting. Due to poor germination of the seed only a few plants of some strains or varieties were obtained. In most cases, however, a fair number of plants grew to maturity.

DISCUSSION AND COMPARISON OF RESULTS

As will be noted from an examination of the table, varieties belonging to all the seven main groups of sorghum (broom corn, VARIETAL RESISTANCE OF SORGHUMS TO SPHACELOTHECA SORGHI (LINK) CLINTON AND SPHACELOTHECA CRUENTA (KÜHN) POTTER

Variety	Seed No.	*Sphacelotheca Sorghi*			*Sphacelotheca cruenta*						
		No. Plants	No. Inf.	Per Cent Inf.	No. Plants	No. Inf.	Per Cent Inf.	Comparison of Plants[3]			
								Normal		Infected	
								No.	Height	No.	Height
Broomcorn, Acme	*180 (C.I. 243)*	22	6	27.2	26	3	11.5	1	3′-10″	1	3′- 0″
" Standard	*199*	45	4	8.8	35	2	5.8	3	8′- 3″	2	4′- 5″
Durra, Brown	*30*	—	—	—	23	10	43.4	5	6′- 3″	10	5′- 3″
" "	*74*	36	12	33.3	—	—	—	—	—	—	—
Darso	*49*	20	0	0	—	—	—	—	—	—	—
"	*165*	39	0	0	25	6	24.0	10	4′- 4″	6	3′- 9″
"	*225 (Tex. Sta. 2897)*	22	0	0	20	13	65.0	7	3′-11″	13	3′- 3″
"	*234 (C.I. 615)*	23	0	0	—	—	—	—	—	—	—
Feterita	*182 (C.I. 182)*	39	0	0	—	—	—	—	—	—	—
"	*222 (F.C.I. 2157)*	30	0	0	39	0	0	—	—	—	—
" , Spur	*151 (Tex. Sta. 3232)*	9	0	0	—	—	—	—	—	—	—
" "	*183 (C.I. 623)*	37	0	0	36	0	0	—	—	—	—
" "	*226 (Tex. Sta. 3232)*	10	0	0	15	0	0	—	—	—	—
Hegari, Dwarf	*84*	9	0	0	6	0	0	—	—	—	—
" "	*148 (S.P.I. 34911)*	5	0	0	—	—	—	—	—	—	—
Kafir, Blackhull	*153 (F.C.I. 2036)*	3	3	100	—	—	—	—	—	—	—
" "	*184 (C.I. 204)*	20	8	40	23	5	21.7	11	3′- 4″	5	2′- 4″
" "	*185 (C.I. 71)*	40	12	30	47	9	19.1	14	4′- 5″	9	4′- 0″
" "	*223 (F.C.I. 2165)*[4]	67	20	29.8	85	12	14.1	19	4′- 9″	11	4′- 0″
" "	*223 " "*[5]	172	73	42.4	113	39	34.5	61	3′- 0″	39	2′- 1″
" "	*227 (Tex. Sta. 6022)*	37	8	21.6	37	5	13.5	5	4′- 2″	5	4′- 3″
" Dawn	*154 (F.C.I. 1932)*	22	4	18.1	—	—	—	—	—	—	—
" "	*186 (C.I. 340)*	37	16	43.2	47	13	27.6	23	3′-10″	9	3′- 1″
" "	*228 (Tex. Sta. 673)*	6	3	50.0	24	5	20.8	15	3′- 9″	5	3′- 5″
" Pink	*155 (F.C.I. 1930)*	26	9	34.6	17	5	29.4	7	4′- 7″	5	3′- 8″
" " (Late)	*156 (F.C.I. 9139)*	12	1	8.3	—	—	—	—	—	—	—

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number of infected plants. Out of a total of 45 plants of both strains, 19 were infected.

The results with Dwarf milo differ entirely from those obtained by Kulkarni (20). As already noted, he states that he secured fifty infected heads out of a total of 645, a percentage of infection of 7.8 per cent. In the course of the present experiments, 99 plants of Dwarf milo belonging to three different strains were grown and none of them were infected.

DIFFERENCES IN THE PATHOLOGICAL EFFECTS OF THE TWO KERNEL-SMUTS OF SORGHUM

Sphacelotheca Sorghi and *S. cruenta* produce quite different effects on the host plants, which may be compared as follows:

1. One of the most obvious differences observed was in the date of emergence of the heads of normal and infected plants. Plants infected with *Sphacelotheca Sorghi* headed out at the same time as normal plants. On the other hand, plants infected with *S. cruenta* headed out very much earlier than the noninfected plants. Practically all of the heads of the smutted plants had fully emerged before any normal heads appeared in the row. Brefeld (3, 4) first called attention to this fact in connection with his experiments with this smut.

2. There was no difference observed in the height of plants infected with *Sphacelotheca Sorghi* as compared with the normal plants. In one or two cases exact measurements were made, but no differences were found. Certainly, as one observed the rows of plants, the infected plants were fully as tall as the normal.

In the case of *Sphacelotheca cruenta* the difference was very striking. Almost invariably the infected plants were 6 inches to a foot or more shorter than the normal. In the table the measurements of both normal and infected plants are given. Normal plants of durra average a foot taller than the infected plants, normal plants of darso 6″–8″ taller, normal plants of the various kafirs 6″–12″ taller, normal plants of kaoliangs 2 feet or more taller, normal plants of shallu 1½ feet taller, normal plants of sorgos 1–2 feet or more taller. In only a few cases did the infected plants average as tall or taller than the normal.

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3. In general appearance, the plants infected with *Sphacelotheca Sorghi* resembled the normal plants. On the other hand, plants infected with *S. cruenta* showed a marked tillering and branching. In many cases an unusual number of tillers originated at the ground level, and there was also an increased development of side branches on the main stem. Consequently, young, smutted heads appeared from lateral branches during the growing season. There was, of course, some branching in the case of plants infected with *S. Sorghi*, but this did not seem to differ in any way from the normal plants.

4. Plants infected with *Sphacelotheca cruenta* sometimes showed a marked enlargement of the glumes. This was particularly the case in the Brown durra. On the other hand, *S. Sorghi* does not seem to produce any change of this character in any variety of sorghum. (See pl. 14, figs. 1 and 9.)

5. The heads infected with *Sphacelotheca Sorghi* are compact and about the same size as the normal, or even larger, due to the increased size of the smut balls as compared with the normal kernels. On the other hand, heads infected with *S. cruenta* are much more slender, with a somewhat looser arrangement than in the case of normal heads. (Compare pl. 14, figs. 1 and 2, and pl. 15, figs. 11 and 12.)

6. The sori of *Sphacelotheca Sorghi* are confined to the flowers. The ovary is converted into the enlarged smut balls. *S. cruenta*, however, may produce sori on the pedicels or other parts of the panicle as well as in the flowers. This has been emphasized as one of the characteristic features of this smut. During the past season, however, a single head of Red Amber sorgo, out of many hundreds of heads observed, showed sori on the pedicels or branches of the panicle.

7. The smut balls of *Sphacelotheca Sorghi* are more or less conic and possess a comparatively thick, tough membrane, which persists for a considerable period and which stands a great deal of weathering. The smut balls of *S. cruenta* are much longer, more slender, and cylindric in shape. They also break open very readily and permit the distribution of the spores. This rupturing of the membrane occurs even before the smut ball has completely emerged

from the glumes. The membrane is light-grayish in color and is very thin and delicate. It is composed of nearly spheric cells, which are much larger than the spores and which readily separate from each other. The cells of the membrane of *S. Sorghi* are smaller, somewhat elongated, and adhere together. (Compare pls. 14 and 15.)

8. The central columellae of the smut balls of *Sphacelotheca cruenta* are much longer, more slender, and curved than those of *S. Sorghi*. Due to the early dissemination of the spores in the field they are quite conspicuous on the maturing plants. (Pl. 14.)

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BROOKLYN BOTANIC GARDEN.

EXPLANATION OF PLATES

PLATE 14

Fig. 1. *Sphacelotheca cruenta.* Infected head of Brown durra. Smut balls emerging between enlarged glumes. ⅘ nat. size.

Fig. 2. *S. cruenta.* Infected head of Brown durra. Late stage, spores largely disseminated and columellae visible. ⅘ nat. size.

Fig. 3, 4. *S. cruenta.* Darso, early and late stages. 4/5 nat. size.

Fig. 5, 6. *S. cruenta.* Black Amber sorgo, early and late stages. 4/5 nat. size.

Fig. 7, 8. *S. cruenta.* Shallu, early and late stages. 4/5 nat. size.

Fig. 9, 10. *S. cruenta.* Brown durra, early and late stages. 4/5 nat. size.

PLATE 15

Fig. 11. *S. Sorghi.* Infected head of Brown durra. 1/2 nat. size.

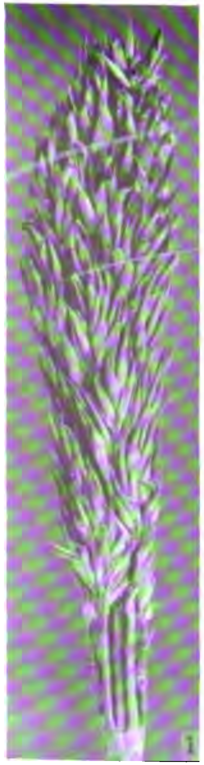
Fig. 12. *S. Sorghi.* Normal head of Brown durra. 1/2 nat. size.

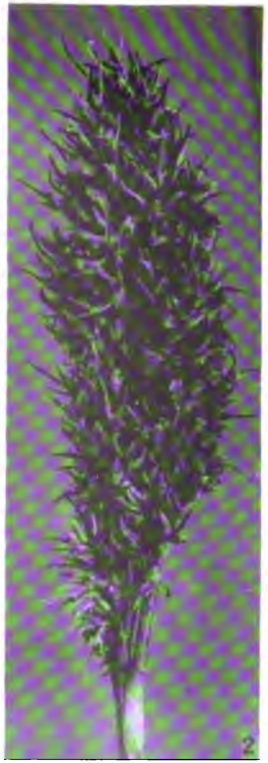
Fig. 13. *S. Sorghi.* Branch of infected head of Brown durra. 2/3 nat. size.

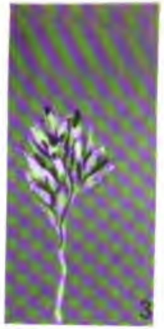
Fig. 14. *S. Sorghi.* Branch of normal head of Brown durra. 2/3 nat. size.

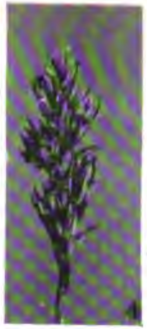
Fig. 15. *S. Sorghi.* Branch of infected head of Dawn Kafir. 2/3 nat. size.

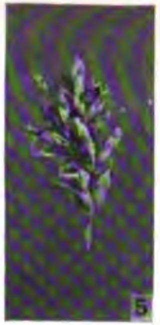
Fig. 16. *S. Sorghi.* Branch of normal head of Dawn Kafir. 2/3 nat. size.

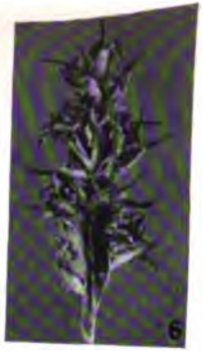


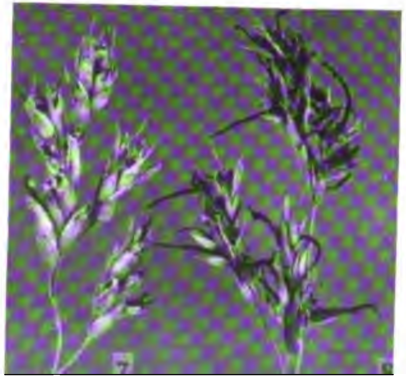


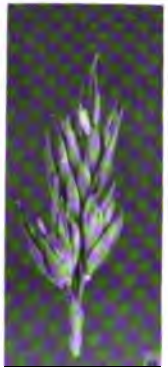


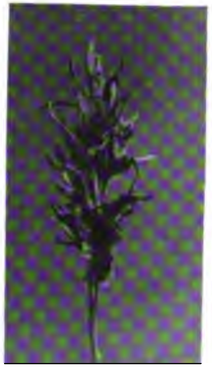












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